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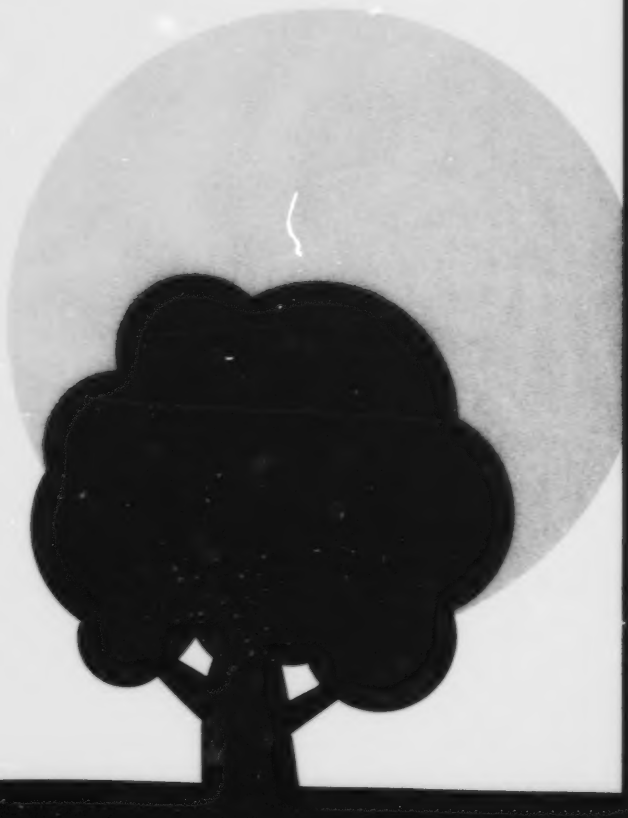

Canada

DESIGN AND PERFORMANCE OF WOOD-CHIP-FIRED STOKERS AND PRE-HEATERS (OUTPUT RANGE 25 TO 75 KW)

7- 6003

FINAL REPORT

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Executive Summary

Large industrial particulate fuel burners have been in use for a number of years in Canada. Recently we have seen the introduction of smaller units in the 25 to 75 kW range. They have the potential for efficient, low-emission automatic combustion. When sold as unit appliances, particulate fuel burners can be certified to CSA B366.1, a standard for solid-fuel-fired central heating appliances. Scandinavian countries have introduced stokers and pre-heaters for chip combustion. These appliances are designed to be coupled to existing heat exchangers fabricated by a third party unknown to the manufacturer. No information is available on the safety, efficiency and emissions level of these combinations.

This study establishes a data base from tests carried out on seven small particulate fuel burners. These were coupled to a variety of wood furnaces and boilers which were used as heat exchangers. Tests were conducted on a variety of fuel types and moisture contents. Test procedures were performed in accordance with CSA safety and performance standards for solid-fuel-burning appliances.

This study has demonstrated that stoker or pre-heater combinations can produce safe, economical heat with very low pollution levels from a variety of particulate fuels. At a fuel burn rate of 3 kg/h (which is high for a residential furnace and low for a stoker), the emissions from a stoker would be perhaps one-tenth of the emissions from a furnace. It has also clearly demonstrated that no single unit was capable of properly handling and burning the wide variety of fuel types and moisture contents tested although some units managed most fuels quite acceptably. Fuel delivery mechanisms were often found to be unreliable except with pelletized fuels.

The introduction of this technology in Canada will permit a more efficient use of biomass wastes. Participation by Canadian manufacturers in the development of these technologies should be encouraged. To ensure that these appliances are safe, efficient and non-polluting, certification to CSA safety and performance standards should be mandatory.

Résumé

Au Canada, les alimentateurs automatiques de particules de bois sont utilisés pour le chauffage industriel depuis déjà plusieurs années. Récemment, nous avons vu l'introduction de plus petits modèles variant entre 25 et 75 kW. Ces appareils sont capables d'un haut rendement et d'une combustion très propre. Il est possible de faire homologuer ces appareils à la norme B366.1 de l'ACNOR si l'alimentateur, la chambre de combustion et l'échangeur de chaleur sont définis comme un ensemble. Ils tombent alors sous la définition des "Appareils à combustibles solides pour chauffage central". Récemment, plusieurs alimentateurs de combustion et de précombustion ont fait leur apparition au pays. Ils nous viennent souvent des pays scandinaves. Ce genre d'appareils a été conçu pour être accouplé à un générateur d'air chaud ou à une chaudière à combustible solide qui leur sert d'échangeur de chaleur. Aucune norme n'a été prévue pour les mettre à l'essai. Il est donc légitime de s'interroger sur leur sécurité, leur rendement et la pollution atmosphérique qu'ils peuvent causer.

La présente étude établit une base de données à partir d'essais effectués sur sept brûleurs de particules. Ces brûleurs ont été raccordés à une variété de générateurs d'air chaud et de chaudières à bois leur servant d'échangeurs de chaleur. Certaines combinaisons d'appareils furent testées avec une variété de combustibles en particules ainsi que sur une vaste gamme de teneurs en humidité. Le déroulement de tous ces essais s'est fait en conformité avec les normes de l'ACNOR se rapportant à la sécurité et à la performance des appareils à combustible solide.

Ces essais nous ont démontré que les alimentateurs de combustion aussi bien que les alimentateurs de pré-combustion peuvent opérer de façon sécuritaire et économique tout en produisant un niveau très bas de pollution, pour une variété de combustibles en particules. A un taux de combustion de 3 kg/h (un débit élevé de chaleur pour un générateur d'air chaud résidentiel mais bas pour un alimentateur automatique), les émissions provenant d'un alimentateur automatique sont le dixième de celles provenant d'un générateur à air chaud au bois. Il est aussi clairement démontré qu'aucun des alimentateurs automatiques n'a pu manipuler avec succès toute la gamme de combustibles particulaires et toutes les teneurs en humidité, quoique quelques unités ont réussi une performance acceptable avec plusieurs combustibles. Les mécanismes d'alimentation de ces appareils ne se sont pas avérés très fiables sauf pour l'utilisation de granules de bois comprimé.

L'utilisation plus répandue de cette technologie au Canada permettrait une utilisation plus efficace des résidus de biomasse. La participation des manufacturiers canadiens au développement de ces technologies devraient être encouragée. Pour s'assurer que ces appareils sont sécuritaires, efficaces et non polluants, on devrait exiger leur conformité aux normes de l'ACNOR.

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1.0 INTRODUCTION

The forest has long been a vital source of raw material in Canada. At first the products were logs for construction, and fuelwood. Gradually many other products - lumber, pulp, and plywood - became important while the importance of fuelwood decreased in areas served by coal, hydro, oil, gas and, very recently, nuclear power. Now, once again, the forest is becoming important to many Canadians as a source of energy for space heating. In most parts of Canada coal is uneconomic, few new hydro sites exist, nuclear poses an enormous threat, and the price of oil and gas is bound to rise relative to the price of biomass. Canadians question the wisdom of buying foreign oil when its replacement by biomass would create local employment.

A national survey in 1983 indicated that 7% of Canadian households obtain at least 50% of their heat from burning wood and another 17% obtain up to 50% from wood. In many forested areas it is common to find 70 to 90% of the households using wood for space heating. In many households it is the labour and inconvenience of wood burning that bars its use. In others it is the emissions from furnaces, boilers, and dirty stoves that have persuaded the householder against conversion to wood. Small-scale, chip-fired combustion offers an opportunity to convert many of these remaining households. The technology is in widespread use in Scandinavia, and is on the verge of adoption and improvement in Canada. Normal small-scale chip combustion is far cleaner than normal roundwood combustion in a central heating system.

Many people fear the impact of increased biomass heating on our remaining decimated forests. However, they do not realize the enormous volumes of low-grade forest material and forest products industry residues that are available for combustion. Also, if the junkwood is removed from a forest for fuel production, the productivity of the forest will be improved. (There is always the danger that all wood, including young healthy trees that should be retained for the next crop, will be harvested because unit harvesting costs vary inversely with the volume harvested per hectare; it is the old problem of management vs greed.)

Other people fear the "greenhouse effect", i.e. increased levels of CO_2 in the atmosphere. As long as the forest is replaced, there is no increase in CO_2. Replacement of scrub forest by vigorous forest reduces the net CO_2 level.

The performance testing of chip-fired stokers, pre-heaters and heat exchangers described in this report was carried out to evaluate the safety, reliability, efficiency, and emissions characteristics of this equipment. A parallel objective was to develop the information necessary to revise several Canadian Standards Association (CSA) standards to accommodate chip-fired systems in addition to roundwood systems.

NOMENCLATURE:

In order to facilitate comprehension of the terminology used in this report, the following definitions[1] are presented.

Stoker: a mechanical device that feeds particulate fuel into a combustion chamber. Burning takes place inside the structure of the heat exchanger. The stoker requires connection to a heat exchanger which is usually a warm-air furnace or boiler. A stoker may include a grate or a retort or a combustion bowl.

Stoker system: means a complete central heating appliance that consists of two units - a stoker and a compatible combustion-chamber/heat-exchanger assembly. Both units are supplied as an integrated central heating appliance by a single supplier and may or may not be fabricated by the same manufacturer.

Pre-heater: means an appliance which includes a stoker and a free-standing, or at least separate, combustion chamber. The stoker supplies particulate fuel to the combustion chamber where the fuel is burned completely. The pre-heater requires connection to a heat exchanger which can, in some cases, be a suitably modified warm-air furnace or boiler.

Pre-heater system: means a complete central heating appliance that consists of a pre-heater and a compatible heat exchanger. Both units are supplied as part of an integrated central-heating appliance by a single supplier and may or may not be fabricated by the same manufacturer.

Unit appliance: means a complete central-heating appliance made by one manufacturer, supplied as a single piece of equipment, regardless of the type of combustion system that it uses, stoker, pre-heater or gasifier.

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[1]Terminology presented by Prof. C. A. Short at the Chip Combustion Workshop sponsored by EMR and held in Rockland, Ontario on June 7 and 8, 1988.

2.0 OBJECTIVES

The objectives of this research program were:

1) To determine whether a wood-chip stoker or pre-heater can be safely retrofitted to a wood-fired furnace or boiler that is to be used as a heat exchanger.

   What types of problems can we expect from coupling and operating these appliances?

2) To determine the efficiency and particulate emission levels of the various retrofit combinations.

   Are stokers more efficient than pre-heaters? Are wood boilers better heat exchangers than wood furnaces? Which particulate fuel type burns best? To what extent do fuel characteristics affect emissions?

3) To recommend modifications to CSA standard B366.1 and B415 to accommodate stokers and pre-heaters. (Most of this information has been presented in a separate report.)

3.0 METHODOLOGY

Many of the procedures used in this project were developed at the beginning of the test program. This approach involved considerable repetition as test procedures were continually improved.

3.1 General observations

General observations were carried out as the appliances were set up, coupled, instrumented and tested. Each particulate fuel burner was installed and operated according to the manufacturer's instructions, when available.

During the many tests (B415, dilution tunnel, high-fire, feed, bridging, burnback, and holdfire) we recorded all operational particularities. We observed two of the stokers, the TP2000 30 kW and 50 kW, operate in actual heating service for several months.

In all, 3 stokers, 3 pre-heaters and 1 unit appliance were tested. These were coupled to 14 different heat exchangers (6 boilers and 8 furnaces). Nine different fuel types were used. Observations stem from all these different combinations.

3.2 CSA B415 performance testing (efficiency and emissions)

The CSA B415 standard for efficiency and emissions testing was developed for use with roundwood fuels in stoves. IRTA modified it for use with particulate fuels.

3.2.1 B415 testing - efficiency

The CSA B415 standard **"Performance Testing of Solid Fuel Burning Appliances"** describes a test procedure for measuring the overall efficiency and emissions levels of free-standing woodburning appliances at various firing rates. The test involves the calculation of the chemical energy loss (smoke) and heat loss (hot gases) up the chimney. It also measures the total amount of particulates (tars and carbon) produced by incomplete combustion. The procedure involves the burning of a standard wood charge. Flue gas temperature, CO_2, CO, O_2 and the steadily decreasing weight of the fuel charge are monitored. Particulate emissions from each combustion are measured using a dilution tunnel. For details of this test procedure refer to the CSA B415 standard.

3.2.2 B415 testing: dilution tunnel

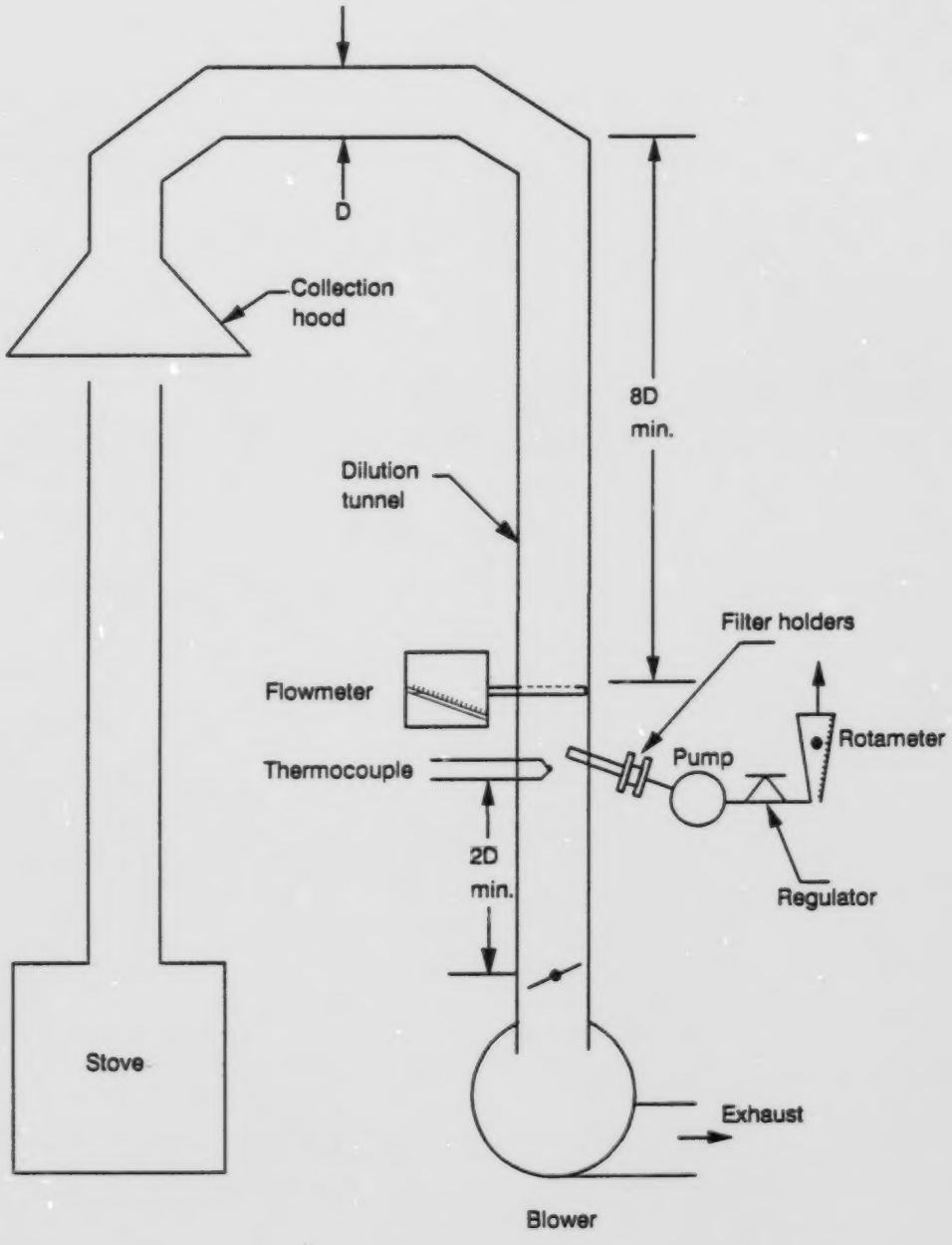
Dilution tunnel testing is one component of the B415 test standard. It is relatively easy to perform and gives a good indication of how cleanly an appliance burns. It is very suitable for in-plant product development testing. The dilution tunnel test measures only particulate emissions. It does not measure gaseous emissions, efficiency or output. The apparatus necessary for dilution tunnel

testing is shown in Figure 1. The total volume of flue gas leaving the appliance is routed through a tunnel where it is mixed with ambient air. Then a known proportion of the diluted gas flow is pumped through a pre-weighed filter. The filter is re-weighed after the burn. The difference is the weight of the particulate matter trapped by the filter. Since the sample that was passed through the filter was a known proportion of the total volume, the total weight of the particulates emitted can be calculated. The weight can be averaged over time to give a reading in grams per hour (g/h) or it can be divided by the mass of dry wood burned to give a reading in grams of particulate emissions per kilogram of fuel (g/kg) or grams per megajoule (g/MJ) of heat output.

The dilution tunnel method is especially useful in that it provides a means to compare appliance emissions to the compulsory U.S. EPA emission standards.

Figure 1.

Apparatus used in dilution tunnel tests[2]



[2]Taken from the CSA B415 standard "Performance Testing of Solid Fuel Burning Appliances".

3.2.3 Modifications to B415 test procedure

The B415 test procedure was designed for testing manually-controlled space heaters, at constant combustion air settings. We modified the procedure to deal with thermostatically-controlled central heating systems burning roundwood, and with stokers and pre-heaters burning particulate fuel.

a) For furnaces burning roundwood

For B415 testing, the furnaces are operated so as to provide constant heat output throughout the test. A dataloger monitors plenum temperatures and operates the furnace's combustion air damper to maintain temperatures within preset limits, simulating thermostatic control. A complete CSA B415 test normally includes 4 different burns which range from the lowest to the highest outputs attainable by the furnace.

b) For boilers burning roundwood

With boilers, the different burn rates were obtained by controlling the rate of flow of cold water return. For each of the controlled flow rates the draft regulator would open or close to maintain boiler temperature.

The heat output for each burn rate was read with a Btu meter. The meter measured the flow rate of water through the boiler and its temperature rise, giving a direct reading of heat output.

c) For stokers and pre-heaters burning particulate fuel

The CSA B415 procedure required several modifications for testing stokers and pre-heaters.

- the standard Douglas fir lumber (moisture content 16 to 20% wb) used as test fuel was replaced with a variety of particulate fuels. The weight of the fuel charge no longer depended on the size and geometry of the combustion chamber. The moisture content of all fuel is expressed in terms of wet base (wb), i.e. (weight of water/weight of wood + water) x 100.

- particulate fuel feed rates were used for the B415 calculations. These feed rates were determined by testing.

- the particulate fuel was not restricted to a moisture content between 16 and 20% wb. For B415 testing we maintained the moisture content of hardwood chips between 31 and 39%. For sawdust, moisture content was held between 40 and 55%. As a separate test, we also used particulate fuel at several different moisture contents to determine the effect on combustion characteristics.

- the different burn rates were achieved via control settings consistent with the manufacturers' written instructions.

- constant fuel composition was used in the B415 calculations as opposed to the variable composition used when dealing with roundwood.

3.2.4 Heat transfer efficiency

For best performance of the stoker or pre-heater, a sufficient amount of heat must be extracted from the flue gases by the furnace or boiler to which it is coupled.

To establish these heat exchange characteristics, we monitored ambient and flue gas temperatures during all dilution tunnel tests. The temperature difference tells us how well the heat exchanger transfers heat. The lower the stack temperature, the more efficient the heat exchanger.

3.2.5 Particulate fuels

a) Fuel types

All particulate-fuel-burning appliances were tested with two fuel types - hardwood chips and sawdust. A few of the appliance combinations were tested with additional fuels.

The first few appliances were tested with a sawmill chip which later proved to be too large for the feed mechanism of the Vallsta, Iwabo and Dan Trim. We used a smaller, screened chip with these three appliances. The TP30 kW, TP50 kW, Swebo, and Tilley used the larger hardwood sawmill chips.

i) Hardwood chips

Chips were purchased from a nearby sawmill. While these chips were of good uniform quality (single species, no bark), they had some long splinters and a high proportion of very small chips. 75% of the chips passed through a 12.5 mm (1/2-inch) sieve (ref. sieve analyses Appendix C). Both these characteristics were found to be a hindrance and led to blockages in the auger feed mechanisms and to compaction of fuels in the bins. The moisture content of these green chips varied between 31 and 38%.

Smaller hardwood chips were made from a load of firewood. These were screened to remove the longer splinters (ref. sieve analyses Appendix C). The firewood was mostly freshly-cut maple. The moisture content of the smaller hardwood chips varied from 31 to 40% over the test period.

ii) Sawdust

Sawdust was obtained from a small sawmill. The sawdust was a mixture of softwood and hardwood, and was of good uniform quality but had some long splinters and pieces of bark (ref. sieve analyses Appendix C). The sawdust had been piled outside and exposed to rain; the moisture content ranged from 40 to 50%.

iii) Additional test fuels

In order to gather comparative data on the combustion characteristics, maintenance requirements and the cost effectiveness of different fuel types, tests were performed with a large number of particulate fuels using some of the appliance combinations. A list of these additional test fuels is shown in Table 1. For more details on the fuels, see Appendix D.

Table 1. Additional Fuel Types

Fuel	Moisture content w b	Source	Comments
1.* hardwood chips	31-38%	local lumber mill	presence of long splinters
* screened hardwood chips	31-40%	chipped from firewood	chipped at EMR CANMET facilities
2.* sawdust	40-50%	local sawmill	mix of soft and hardwood chips
3. softwood chips	50%	logging company	
4. whole tree chips-softwood	55%	" " "	mix of softwood chips and treetop chips
5. chips from slabs	40%	" " "	stockpiled slabs chipped at logging co.
6. ground bark	45%	lumber company	when picked up fuel was at 62% m.c.
7. fines from screening chips	45%	" "	when picked up fuel was at 62% m.c.
8. wood pellets	8%	local distributor	pellets manufactured by N.S. Bauman Ltd, Wallenstein, Ontario
9. peat	25-35%	Avalon Peat Harvesting,	peat chunks were cylindrical, 25cm long and 5cm wide
peat pellets		St. Shotts, Nfld.	peat was pelletized by N.S. Bauman Ltd
* standard test fuels - a sieve analysis of these fuels may be found in Appendix C			

b) Fuel storage, handling and conditioning

i) Storage and handling

Fuels were collected in grain bags, stored outdoors and protected from the rain. The fuel bags weighed anywhere from 5 kg (11 lb.) for dried sawdust to 25 kg (55 lb.)for green hardwoods. This bagging of fuel was found to be a practical way of handling the numerous fuel types. Bagged fuel also made the filling of surge bins easier.

The sawmill chips were stored in a grain silo. As quantities were required, they were bagged and transported to the test facility.

Initially the wood pellets were stored outdoors under cover. We quickly discovered that even though the pellet bags were covered, they picked up moisture. This caused us to lose 15 to 20 bags of pellets as the fuel disintegrated. We salvaged parts of these bags by screening the material. Our supply of pellets was then moved indoors.

ii) Conditioning

For our test methodology, hardwood chips were maintained within a 31 to 40% moisture content range. For sawdust our range was from 45 to 55%. Some of the appliances were not able to burn the wetter sawdust. For these, we dried the sawdust to 40%.

To prevent fuels from drying too quickly, fuel bags were stored outdoors in the cold. The hardwood chips stored outdoors dried at a rate of 1 to 2% per month. The sawdust dried at a slower rate.

Fuels were dried when they were either too wet to burn or when we specifically wanted to test them at lower moisture contents. To dry fuels, we spread them indoors, on a concrete floor and forced warm air over them. In the spring, drying was done outdoors. The fuels were spread on tarpaulins in thin layers and were turned over on a regular basis to ensure uniform drying. It was usually possible to lower the moisture content of chip fuels substantially in one single warm, windy day.

For one series of tests, we had to raise the moisture content of chips to unusually high levels. We submerged the bags of fuel in water barrels. This procedure was only followed on one occasion. While moisturizing chip fuel in this manner, we found that we were leaching out components. The soaking water had turned to a very dark brown colour.

iii) Fuel sieve analyses

Sieve analyses were performed on the three standard test fuels, i.e. the two types of hardwood chips and the sawdust. Results may be found in Appendix C. The basic difference between the two hardwood chip types is the 2% that do not pass through the #25 sieve. This small difference may account for the problematic character of this fuel. The long stringy pieces jam the fuel feed mechanisms and are responsible for many of the blockages.

Test results with sawdust show that close to 100% of the material passes through a 9.5 mm (3/8-inch) sieve.

The CSA standard CAN/CSA-B366.1-M87 Solid-Fuel-Fired Central Heating Appliances lists in its Table 2 several different wood chip grades, but unfortunately, the specifications do not cover a very wide range of particulate fuel types.

3.3 CSA B366.1 safety testing

3.3.1 High-fire testing

The objective of high-fire tests is to determine whether an appliance combination, be it stoker/heat-exchanger or pre-heater/heat exchanger, will generate unacceptably high temperatures on heat exchanger surfaces. With furnaces, this was accomplished by fixing thermocouples to sides, top and back of the combustion chamber as well as on the flue collar. With boilers, it proved much more difficult trying to record combustion-chamber surface temperatures as the thermocouples had to be fixed on the inside walls.

High-fire test measurements were recorded during dilution tunnel tests. They were done for all fuel types. At first it was thought that the highest possible temperatures would be obtained when the stoker or pre-heater operated at maximum feed rate. However test results showed us that this was not the case because at maximum feed, fuel was being supplied at a rate faster than appliances were able to burn. This maximum obtainable feed rate was also dependent on the heat exchanger's resistance to gas flow. When there was overfeed, the fuel burned slowly and did not generate the highest possible temperatures. The maximum setting for high fire tests was found to be appliance-dependent and had to be determined experimentally for each one of the burner/heat-exchanger combinations.

3.3.2 Feed tests

To determine efficiency, output and particulate emissions, it is necessary to know the rate at which fuel is being burnt by the particulate fuel burner. This is determined by a feed test.

Particulate fuel burners control heat outputs by varying the amount of fuel delivered to the combustion chamber. This fuel feed regulation may be done by changing the auger's speed and/or by cycling its operation. Feed tests measure the quantity of fuel fed by an appliance over a specific time period. This feed rate is then expressed in terms of kg/h of dry fuel.

Appliances with adjustable speed augers had feed tests performed only at the auger's highest operating speed. Tests demonstrated that, at all lower speeds, the rate of fuel delivery is proportional to the change in auger speed.

The Vallsta and Iwabo operated with three pre-determined cycles for feeding fuel: continuous operation, 80 and 50% of continuous operation. Feed tests on all three showed us that the cycling rates were proportional to the continuous rate.

Feed rate tests were performed with all the particulate fuel burners, detached from the heat exchanger. During the feed tests fuel was poked in the surge bin at 10-minute intervals to ensure a steady feed rate.[3] Feed tests were performed every time a different type of fuel was used and whenever the moisture content of the fuel varied by more than 5%. Fuel feed rates were then transformed to dry feed rates for data analysis.

3.3.3 Bridging tests

Bridging of fuel is the condition that occurs inside a surge bin when friction between fuel particles prevents flow. This may result in fuel bridges or rat holes being formed inside the fuel. The bridging will eventually reduce fuel flow or even prevent fuel from reaching the feed mechanism.

The purpose of the bridging tests was to determine whether the stokers or pre-heaters were able to deliver a steady feed rate over extended periods of time. The fire in an appliance may become extinguished even though the fuel bin is full if fuel does not reach the combustion area. Bridging decreases an appliance's reliability.

The fuel agitators or stirring mechanisms used in some of the surge bins were not efficient in ensuring a steady supply of fuel to the auger. Partial or even complete bridging of fuel still occurred.

Bridging tests were carried out over periods which would sometimes reach 10 hours. During bridging tests, the stoker or pre-heater fed fuel into a container placed on a weigh scale. The dataloger recorded the weight at two-minute intervals. Tests continued until

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[3]We also poked the fuel at 10-minute intervals during all firing tests, for the same reason.

we obtained bridging of fuel or had emptied the surge bin. A non-linear plot of cumulative fuel weight against time would indicate bridging. Bridging tests were done with the fuel at the same moisture content as the test fuel.

Initially we installed mechanical vibrators on our fuel bins to help prevent bridging. We soon stopped when we found that the vibration was in fact compacting the fuel in the surge bin. Vibration probably made fuel blockages worse. We decided that the best way to prevent bridging of fuel and to ensure steady feed rates during tests was to poke the fuel at ten-minute intervals.

3.3.4 Burnback

Burnback describes the situation when fuel burns backward inside the feed system, towards the bin. This situation can be very dangerous should the fuel load inside the bin ignite. Initially, we anticipated an elaborate setup to induce burnback. However, we soon found that burnback was easy to obtain under normal operating conditions. Conditions favouring burnback were easily identified.

3.3.5 Hold-fire

Appliances operate in the hold-fire mode when there is no call for heat. In this mode the particulate fuel burner continues to operate at a very slow rate. The principal purpose is to conserve flame for fuel ignition at the next call for heat.

In hold-fire testing, we verified whether the stokers conserved their fire (stayed lit) and whether there was any risk of burnback. We had many occasions to do this, especially on warmer days because we had two appliances equipped with hold-fire which were on continuous operation.

Dilution tunnel testing was also performed with the appliance in the hold-fire mode. The emission levels were compared to those from appliances having automatic ignition.

3.4 Matrix of appliance combinations tested

The considerable number of stokers and heat exchangers presented us with many possible test combinations. These are grouped into the following categories.

A - small stoker or pre-heater with small furnace heat exchanger
B - small stoker or pre-heater with small boiler heat exchanger
C - large stoker or pre-heater with large boiler heat exchanger
D - large stoker or pre-heater with large furnace heat exchanger

The various appliance combinations that were tested are shown in Table 2. Since a full B415 test costs considerably more (in analysis time) than a dilution tunnel (DT) test, only the DT test was used for evaluating many combinations.

Table 2. The Different Appliance Configurations

TABLE 2 THE DIFFERENT APPLIANCE CONFIGURATIONS USED IN TESTING

A - Small stoker or pre-heater with small furnace as heat exchanger

	TP2000 30kW		VALLSTA		DAN TRIM (1)	
	h. chips	sawdust	h. chips	sawdust	h. chips	sawdust
1 Hunter MP-80	B-415	B-415	B-415	B-415	-	-
2 Newmac	DT	DT	DT	DT	-	-
3 Summeraire	DT	DT	DT	DT	-	-
4 Scotsman	DT	DT	DT	DT	-	-
5 Fawcett	DT	DT	DT	DT	-	-
6 Hunter 8018 (2)	B-415	B-415	B-415	B-415	B-415	B-415

B - Small stoker or pre-heater with small boiler as heat exchanger

1 Patlyn	DT	DT	DT	(4)	-	-
2 Boilersmith	B-415	DT	DT	-	-	-
3 Titan	B-415	DT	DT	-	-	-
4 Etna 30 kW (3)	B-415	DT	B-415	-	-	-

C - Large stoker or pre-heater with large boiler as heat exchanger

	TP2000 50 kW		SWEBO (5)(6)		IWABOMATIC		TILLEY	
	h. chips	sawdust	h.chips	sawdust	h. chips	sawdust	h. chips	sawdust
1 Boilersmith	DT	DT	B-415	DT	DT	DT	(8)	-
2 Etna 50 kW (3)	(7)	-	B-415	B-415	B-415	B-415	-	-

D - Large stoker or pre-heater with large furnace as heat exchanger

1 Hunter 8018	(7)	-	DT	DT	DT	DT	-	-
2 Sherbrooke	B-415	DT	DT	DT	DT	DT	-	-
3 Scotsman	B-415	DT	DT	DT	DT	DT	-	-
4 Tilley (8)	-	-	-	-	-	-	DT	DT

DT = Dilution Tunnel

(1) Operational difficulties prevented a full series of tests with the Dan Trim

(2) Hunter 8018 replaces Hunter MP-80

(3) Also B-415 with roundwood

(4) No more testing of Vallsta with sawdust as previous tests showed that fan blows sawdust out of combustor bowl

(5) The Swebo and large Boilersmith were tested with the following 9 fuels

1. hardwood chips
2. sawdust
3. softwood chips
4. whole tree chips - softwood
5. ground bark
6. fines from screening
7. waste wood pellets
8. chips from stockpiled slabs
9. peat and peat pellets

(6) The Swebo and large Etna were tested with

- hardwood chips conditioned to moisture contents ranging from 10 to 55% at 5% intervals
- softwood chips conditioned to moisture contents ranging from 50 to 65% at 5% intervals

(7) TP2000 50kW's combustor bowl was too large for fitting to heat exchanger

(8) Tilley is a unit appliance, a complete system, and was not coupled to any other apliance

4.0 OBSERVATIONS AND DISCUSSIONS ON THE OPERATION OF STOKERS AND PRE-HEATERS AND THEIR RETROFIT TO HEAT-EXCHANGERS

This section contains our observations on the retrofit and testing of the various appliance combinations. In order that these observations be taken in their proper context, we felt it was also necessary to introduce and illustrate the various electrical and mechanical components of particulate fuel burners and discuss their operational particularities. While specific examples are often used, these observations and discussions are meant as general comments on particulate fuel burners.

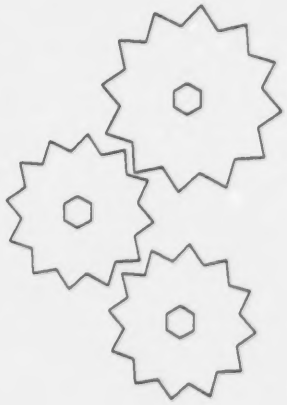
This section is divided into mechanical and electrical components.

The particulate fuel burner performs a function very similar to that of an oil burner on a furnace. It must deliver fuel to the combustion area and burn this fuel efficiently, and there must be provision for removal of the products of combustion. To perform these functions, it must be safely connected to the heat-exchanger. We will examine in sequence each of the functions which the particulate fuel burner must perform.

4.1 Mechanical components (ref. Fig. 2)

4.1.1 Mechanical connection

a) General



The attachment of a particulate fuel burner to its heat exchanger is similar to the attachment of an oil burner to its furnace. The connection must resist the back pressure and high temperatures associated with forced-air combustion. It must also resist pulling and mechanical vibration. Therefore, the attachment of a stoker or pre-heater to a furnace (or boiler) must be secure and air-tight.

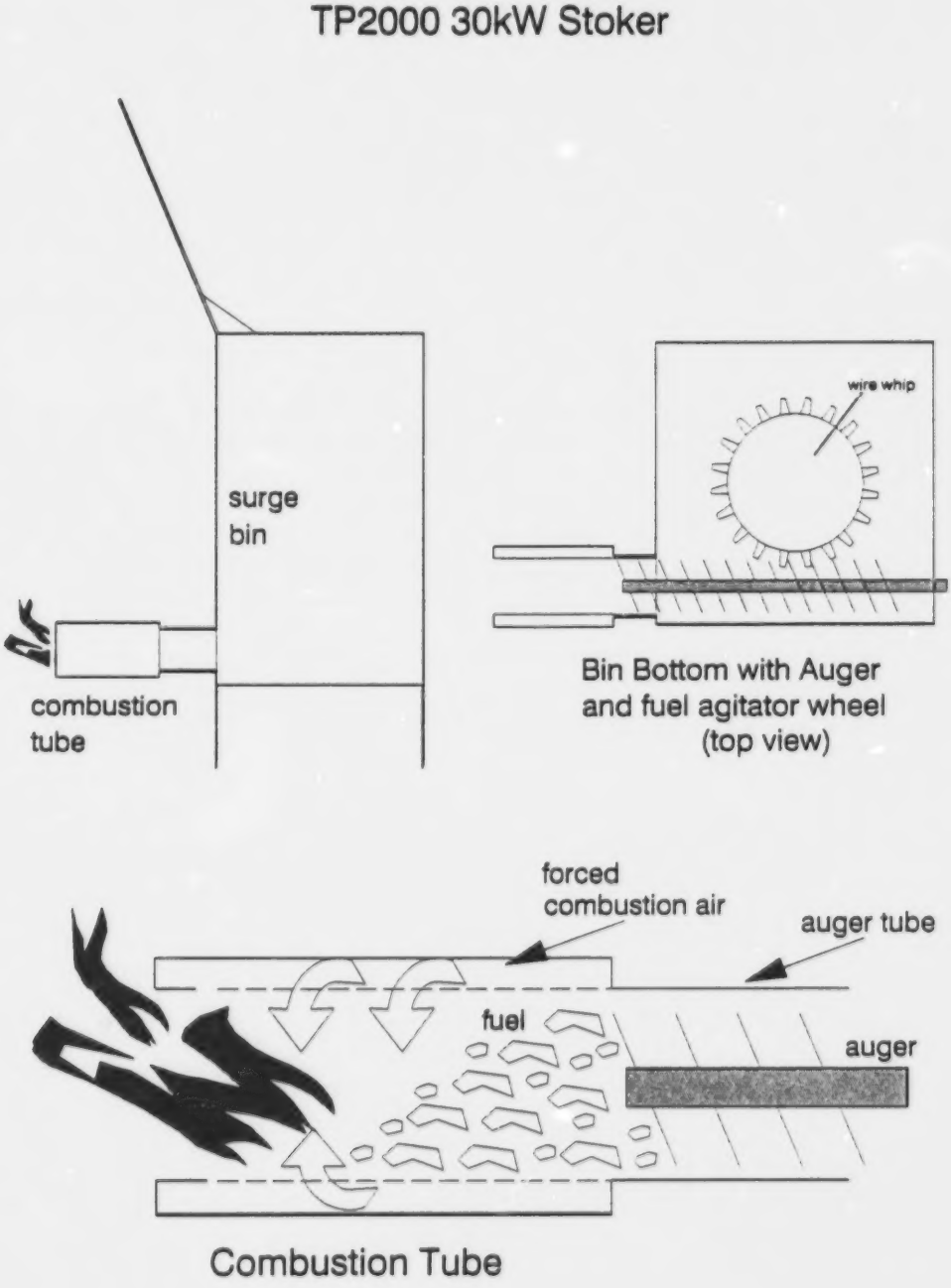
Aside from the Tilley burner which is sold as a unit appliance, the particulate fuel burning appliances used in this study were designed for attachment to heat exchangers unknown to the manufacturer. Their design should permit easy attachment by a professional installer. In some cases, the manufacturers provided the necessary components to facilitate coupling.

i) components fabricated by an installer:

Often the parts necessary for attachment of a stoker or pre-heater to a heat exchanger have to be custom-made. They often require welding, metal fabrication and sealing of overlapping steel surfaces to make airtight joints. Installers must be

Figure 2.

Mechanical components of a stoker



quite knowledgeable in order to achieve a satisfactory coupling.

ii) components fabricated by the manufacturer:

Some heat exchangers have been designed for retrofit to specific particulate fuel burners. For example, the Etna was designed with an opening in its side for coupling to a Swebo stoker. This greatly simplifies the installation and usually makes it safer.

Some stokers are fabricated with combustion bowl flanges which are meant to simplify their installation. They can be adapted with relative ease to a number of appliances. The flanges may be bolted to the heat exchange appliance and sealed with a good quality fibreglass or ceramic fibre gasket. Examples of this are the TP50 and Vallsta.

b) Through-the-door attachment (ref. Fig. 3)

If a stoker is retrofitted through a heat exchanger's loading door, an adapter plate is usually required to achieve a sealed mechanical connection between the two appliances.

Stokers installed through-the-door may have to be rolled back from the heat exchanger frequently for such functions as lighting, maintenance of mechanical components, ash removal and cleaning of heat exchanger surfaces.

While through-the-door retrofits are acceptable, they are not always convenient and not recommended. They do not allow casual inspection of what is happening in the heat exchanger. The TP50 with a full bin is very heavy and difficult to move. The Iwabo and Swebo pre-heaters have both a combustion chamber and a surge bin and are designed for a semi-permanent installation and not to be casually moved back and forth. The Dan Trim requires piping to cool its combustion chamber and cannot be moved. Side fits simplify maintenance tasks. Also, in some cases the operator may wish to burn larger pieces of wood occasionally, and such material must be introduced through the loading door aperture.

c) Through-the-side attachment

i) furnace (ref. Fig. 4 a)

For through-the-side coupling, an opening is cut through the side of the furnace jacket and combustion chamber. If necessary, an adapter plate is welded to the combustion chamber wall. A through-the-side attachment is convenient in that the operator has the option of burning roundwood should problems develop with the operation of the stoker or pre-heater. A sealing plug can be made to close the opening so that the furnace may burn roundwood if the stoker is removed for maintenance. This type of coupling can usually be done with relative ease.

ii) boiler (ref. Fig. 4 b)

Connecting a stoker to a boiler through the side, under the boiler jacket leg, is very similar to a through-the-side furnace coupling. Since this type of installation is usually low (close to the floor), it requires a stoker or pre-heater which has its outlet close to the floor.

If the boiler has a grate, which interferes with this type of installation, it may be best to leave the grate in place so that the boiler can still be used with roundwood, and retrofit the stoker through the boiler wall. Such a connection requires piercing of the boiler walls. This should not be attempted by anyone except a qualified steamfitter, boilermaker or a welder specializing in this type of work. If this type of connection is to be performed on an old boiler with refractory-lined walls, it would be wise to assess the economics of fitting to the old boiler vs buying a new boiler.[4] The following quote is relevant:

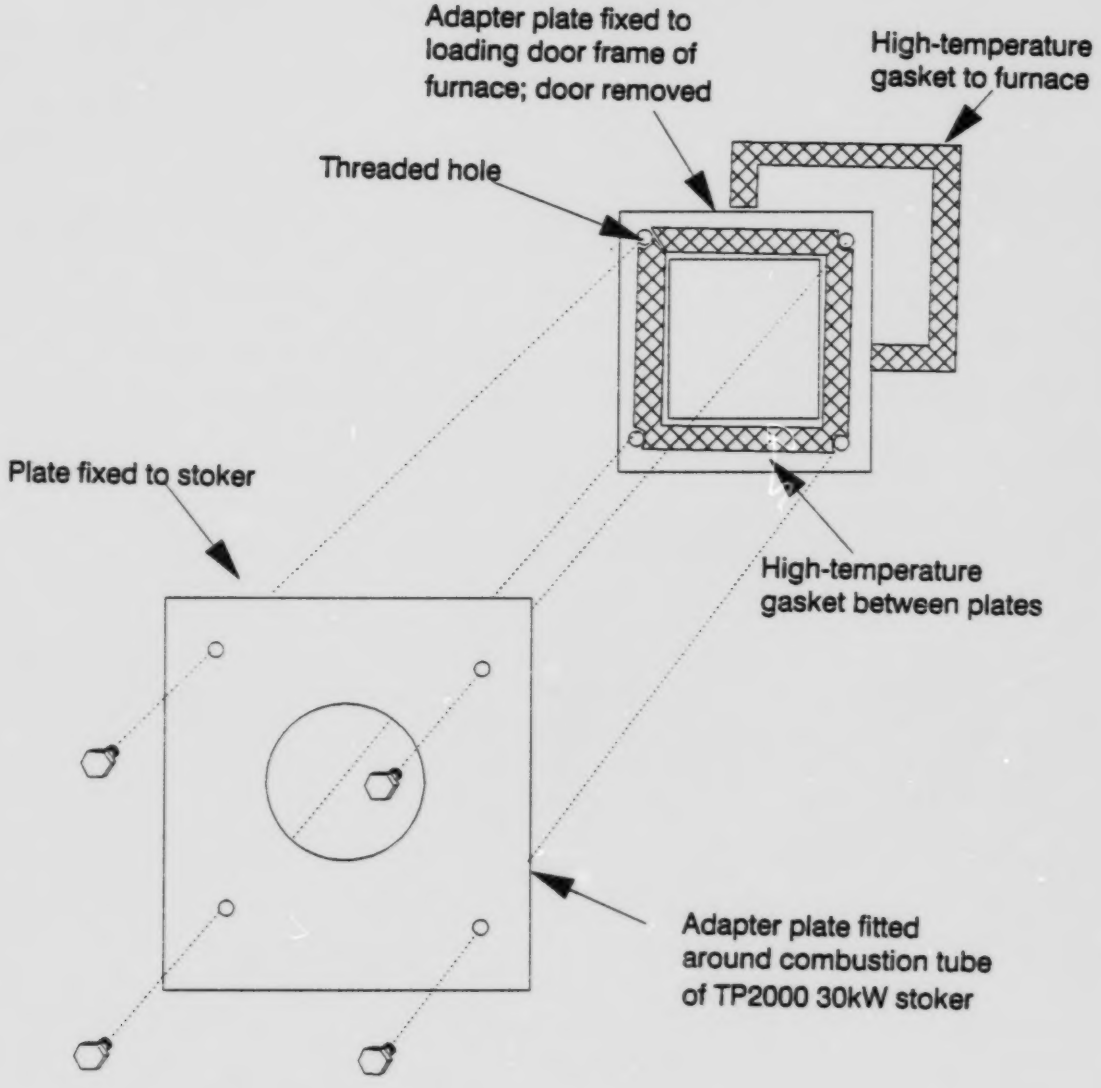
> The Iwabo pre-heater was retrofitted to the existing old oil-fired boiler by means of a side connection. This connection required that an opening be made in the boiler base, under the boiler legs, through a cast-iron plate and the firebrick liner. New refractory had to be poured in place to finish the opening.
>
> Because the existing oil burner was at the bottom of the fire chamber, ashes from the pre-heater could not be removed from the lower front door of the boiler. A new ash-door had to be installed, requiring a second (costly) opening in the boiler base, under the boiler legs, on the opposite side of the boiler...

---

[4]Report to E.M.R. Installation and Operation of an Iwabo Pre-heater for the Blue-Church Nursery in Prescott, Ontario. I.R.T.A. August, 1988.

Figure 3.

Adapter plate for cylindrical combustion tube of TP2000 30kW stoker

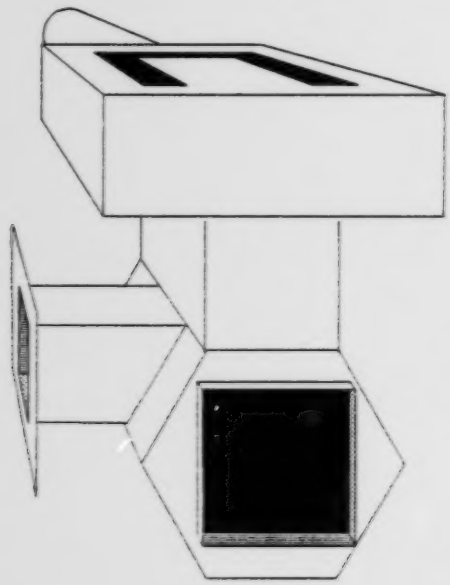

Adapter plate fixed to loading door frame of furnace; door removed
High-temperature gasket to furnace
Threaded hole
Plate fixed to stoker
High-temperature gasket between plates
Adapter plate fitted around combustion tube of TP2000 30kW stoker

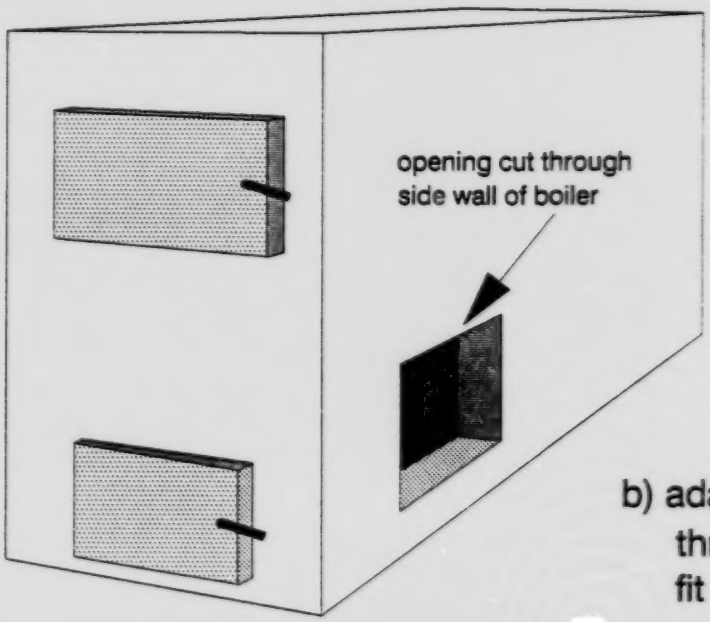
Note: Through-the-door attachments are not recommended.

Figure 4.

Adapters for through-the-side coupling to furnaces and boilers

a) adapter for through-the-side coupling to Hunter furnace





b) adapter for through-the-side fit on a boiler

4.1.2 The combustion chamber and the ignition system

a) The combustion chamber

i) Stokers (ref. Fig. 2, 5)

Stokers are differentiated from pre-heaters by the fact that stokers do not have their own combustion chamber. In a stoker plus heat exchanger combination, the combustion chamber is the location where the particles are brought to burn, with a proper mixture of forced air, within the structure of the heat exchanger. The burn area may be limited to a bowl which is completely open to the furnace or boiler heat exchanger (Vallsta, TP2000 50 kW). In better designs, the combustion may occur in a tube before the gases exit into the heat exchanger (TP2000 30 kW). While this may not be an independent or free-standing combustion chamber as with a pre-heater, the combustion gases are kept much hotter because they are not immediately cooled by contact with heat exchange surfaces.

ii) Pre-heaters (ref. Fig. 6, 7)

Although pre-heaters fall into the general category of stokers, they have a combustion chamber which is independent of the heat exchanger. This has the advantage of minimizing heat loss during combustion and ensuring that heat exchange occurs only after the combustion process has been completed.

iii) Stokers vs pre-heaters

The distinction between stokers and pre-heaters is far from being black and white. As already stated, some stokers such as the TP2000 30 kW have characteristics similar to pre-heaters. While they do not have a full combustion chamber, much of the combustion occurs inside the "combustion tube". Conversely, some pre-heaters have their own combustion chamber but, because of their design, burn their fuel incompletely, with the result that most of the combustion occurs beyond the combustion chamber, within the heat exchanger. The design of a pre-heater's combustion chamber should promote complete fuel combustion.

b) Lighting the stoker or pre-heater

i) Manual ignition

A pre-heater can be lit by lifting the combustion chamber's cover. Fire is started manually with paper and dry kindling, and then fuel is brought into the combustion chamber by activating the feed mechanism. In some cases, it is simpler to use a propane torch. Initial lightup is usually easier if primary air can be supplied independently of the fuel feed, i.e. without the fuel feed operating.

When a stoker is coupled through a heat exchanger's loading door, it is necessary to pull back the stoker for lighting. During lightup, smoke frequently enters the room because the combustion bowl is out of the heat exchanger.

Stokers connected through the side of a heat exchanger can be lit through the loading door opening.

Under actual operating conditions, some stokers or pre-heaters will require lighting only a few times each year.

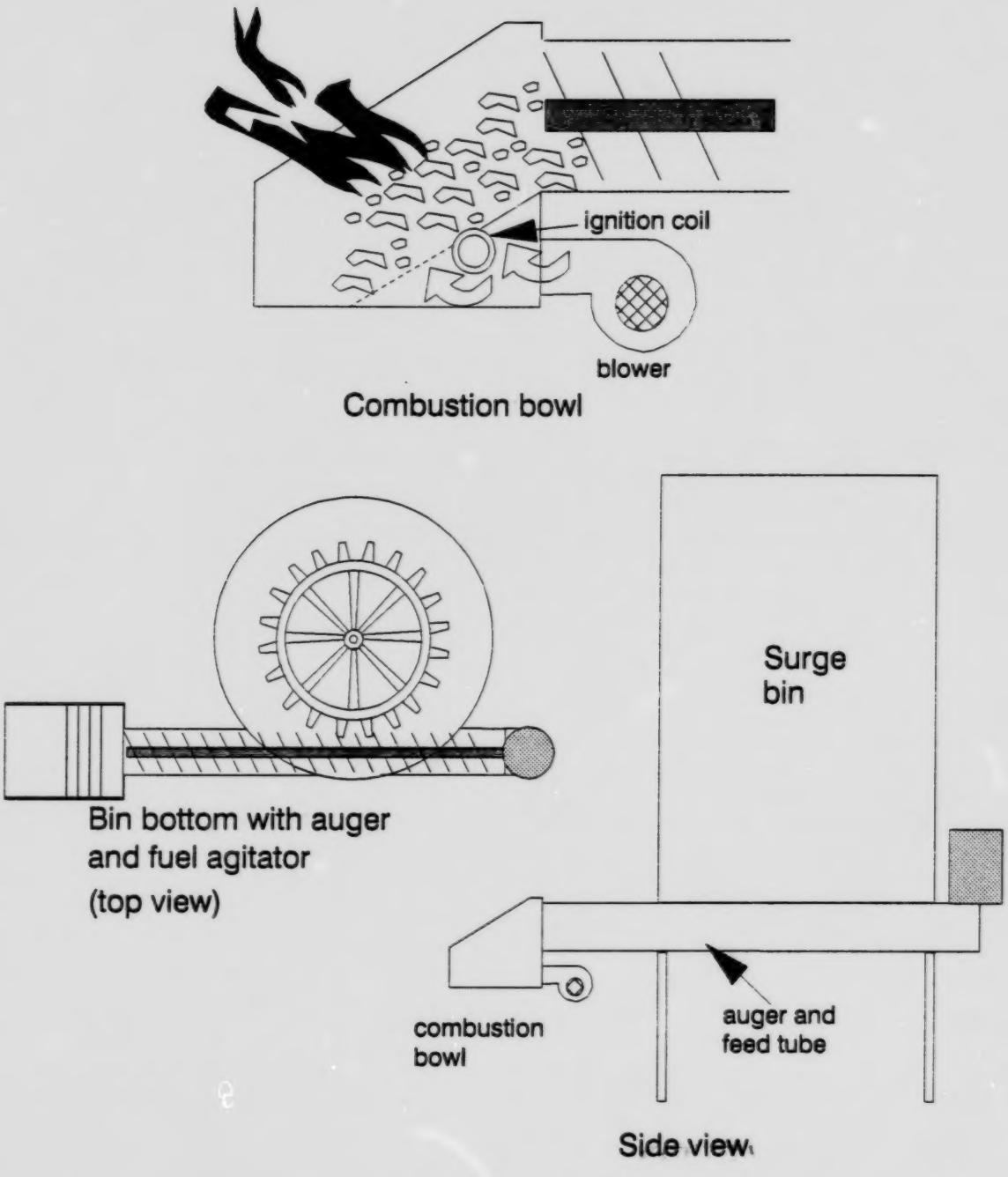
ii) Stokers with automatic ignition (ref. Fig. 5, 6)

Some stokers and pre-heaters are equipped with ignition coils or heat guns. The ignition coil is initially activated by a photocell circuitry, in the absence of visible flame. When there is a call for heat and the photocell does not detect flame, the stoker is automatically brought through a lighting sequence. This sequence usually involves feeding fuel to the combustion area, operating the ignition coil or heat gun and energizing a fan to supply combustion air. If after a fixed time lapse, the flame sensor does not identify fire, it will either shut the appliance down or go through a second lighting sequence, depending on the appliance. Some fuels produce more smoke than others and the sensitivity of the flame detector may have to be increased for specific applications. This is usually done by turning a screw adjustment on the circuit board. In extreme cases, some sensors will not detect flames from smoky fuels even when the fire is well lit. We experienced this when burning sawdust in the Iwabo and Vallsta. In this situation, the fuel cannot be used unless the control circuitry or the sensitivity of the photocell is changed.

While automatic ignition devices have advantages, it must be remembered that a faulty heat gun, a burnt-out ignition coil, dirty photocell or simply a failure to understand the ignition system, might prevent the whole system from functioning.

Figure 5.

Vallsta stoker



4.1.3 Feed section (ref. Fig. 2, 5, 6, 7)

a) The storage bin and material delivery to the surge bin

Surge bins only contain sufficient fuel for a maximum of one to two days. Storage bins can contain a fuel supply for a month or more.

There are several commercial chip storage bins available with different types of delivery systems to bring fuel to the surge bin. These storage bins and delivery systems make the possibility of chip-fired heating systems much more attractive. Their cost is still such that they are only economic for commercial installations although current technology developments may change this prospect. Our work for EMR did not include examination of these larger storage containers.

b) The surge bin

When installing a particulate fuel heating system, consideration must be given to different aspects of the surge bin. What is its capacity, will it fit in the area provided, does it have the proper mechanisms to feed the fuel and what are its limits with regard to fuel type and variability?

i) Capacity

The time between refills is determined by the bin's volume, the heat demand, the energy density of the fuel and the energy conversion efficiency of the stoker/heat-exchanger combination. A full bin of non-compacted planer shavings will provide far less energy than a bin of hardwood chips. A full bin of wet hardwood chips will have less energy potential than a bin filled with air-dried chips.

When sizing a surge bin, it is crucial to determine the peak heating load, the energy density of the fuel most likely to be used, and the length of time the stoker might be left unattended unless there is provision for its automatic refilling.

ii) Shape, size, height

Bin size and shape is limited by the size of the building in which it is used. In many cases, the stoker is retrofitted to a heat exchanger in a building in which no provision was made for the space required for a chip surge bin. The surge bin must be located so that it can be easily refilled from the fuel storage bin. The ceiling height should be sufficient for proper operation of the cover and easy access to the bin. In determining surge bin height, care must be taken to first determine the height above the floor of the connection with the heat exchanger; even if the bin itself is short, it may have to be elevated substantially to accommodate a furnace with a high

combustion chamber. The surge bin and the material from which it is fabricated must be designed to minimize the likelihood of bridging.

iii) Bringing the fuel to the auger: wheels, whips, vibrators, agitators and blades.

- effective mechanisms to prevent bridging

The moving of chips and sawdust is no easy job. Particulate fuels, in general, have a tendency to form "rat holes" and "bridges" inside surge bins. It is common to find that after a few hours of use, the fuel level in the bin has not decreased because the material is completely supported by bridges. Little or no fuel is reaching the auger. Fuel bridging can be partially prevented by proper bin design and by adding agitators such as wheels, whips, or paddles. Different agitator designs are more or less efficient in preventing bridging. It has been our experience that vibrators temporarily alleviate bridging problems but increase compaction. We will comment on individual appliance performance later in this report.

- design to reduce compaction of the fuel in the bin:

Material compaction in the bin occurs when the feed mechanism supplies more material to the auger than the auger can carry away. The surplus material tends to be compacted against the walls of the bin, near the entrance to the auger tube. The amount of compaction varies between appliances. The TP2000 50 kW and 30 kW stokers both had a strong tendency to compact material where the auger exits from the bin. While the Swebo never showed any signs of compaction in our lab, we were informed that it occurred in a nearby installation. The problem was solved by adding an obstruction plate which slowed down the fuel supply to the auger.

- cleaning port

Because particulate fuels tend to compact and long slivers tend to accumulate at the auger exit, it is necessary to periodically clean the bottom of the bin. When the level of chips in the hopper became low on both the TP2000 stokers, we noticed that the hoppers contained a large proportion of longer chips. These longer chips are moved with difficultly through the auger, and if they are not removed on a regular basis they eventually block the auger. We have found that a cleaning port located in the surge bin wall close to the auger exit facilitates removal of accumulated long slivers and oversize chips. This panel also provides ready access to the area where jamming of chips is most common. Some bin shapes, such as that of the Swebo, will not allow practical access through a cleaning port

c) Auger

When evaluating the appropriateness of an auger, we must consider the different designs that are available. It is obvious that, for fuels like unscreened sawmill chips, the auger characteristics will have to be quite different from those needed to transport small uniform pellets. Among the augers being presently used, we must consider the following characteristics:

- the size of the auger tube
- the distance between flights (pitch)
- the clearance between the screw and the tube walls
- the shape of tube: round, square or U-shaped
- flexible or rigid
- full or coreless

Each of the above characteristics influences the capacity of the auger to transport different fuels. There are limits to the size and shape of the fuel particles that each system can accommodate. Some augers cannot transport large pieces because of the relatively small size of the auger tube. Some larger tubes still cannot deal with large pieces due to lack of clearance between the auger and the tube wall or because of the small pitch (i.e. flights too close together).

We experienced numerous blockages of the auger in the Iwabo. Its auger is set in a semi-circular trough at the bottom of the surge bin. Chip buildup beneath the auger in this trough forces the auger up against the upper section of the delivery tube. This increases friction and reduces clearance for chips entering at the top of the delivery tube. Compacted chips jam the auger regularly at this location.

Small auger tubes with a tight-fitting auger screw (e.g. Vallsta) are not meant for large fuel particles. On the other hand, a small auger in a large tube also has problems transporting material. We tried this in the TP2000 30 kW and found that the auger floats on top of a long bed of inert material. The best transport mechanism was found in the Swebo. In this case, the square auger tube seems to offer an advantage although it is clear that small particles linger a long time in the bottom corners. It has been hypothesized that a U-shaped delivery tube would cure this last problem. It is important to ensure that there is no sharp edge or obstruction at the junction of the hopper and the auger tube to hinder the smooth flow of chips.

Apart from particle size, particle shape is also an important characteristic. All feed systems had difficulties with the long stringy pieces which are found in just about all types of biomass

fuel. These tend to accumulate at the bottom of the bin, at the entrance to the auger tube. They accumulate at this particular spot and if they are not removed at regular intervals, they will eventually block the auger feed.

The chip feeding systems we have tested so far, except for the Swebo, have all eventually blocked on one fuel or another. Of course, not all fuels are meant to be used on all appliances but oversized pieces have been found in practically all fuels[5].

[5] We have found that protection is not only needed against blockages caused by large pieces of fuel but also by bolts, pokers, wrenches and even stones which have somehow become mixed with the fuel.

Figure 6.

Iwabo pre-heater

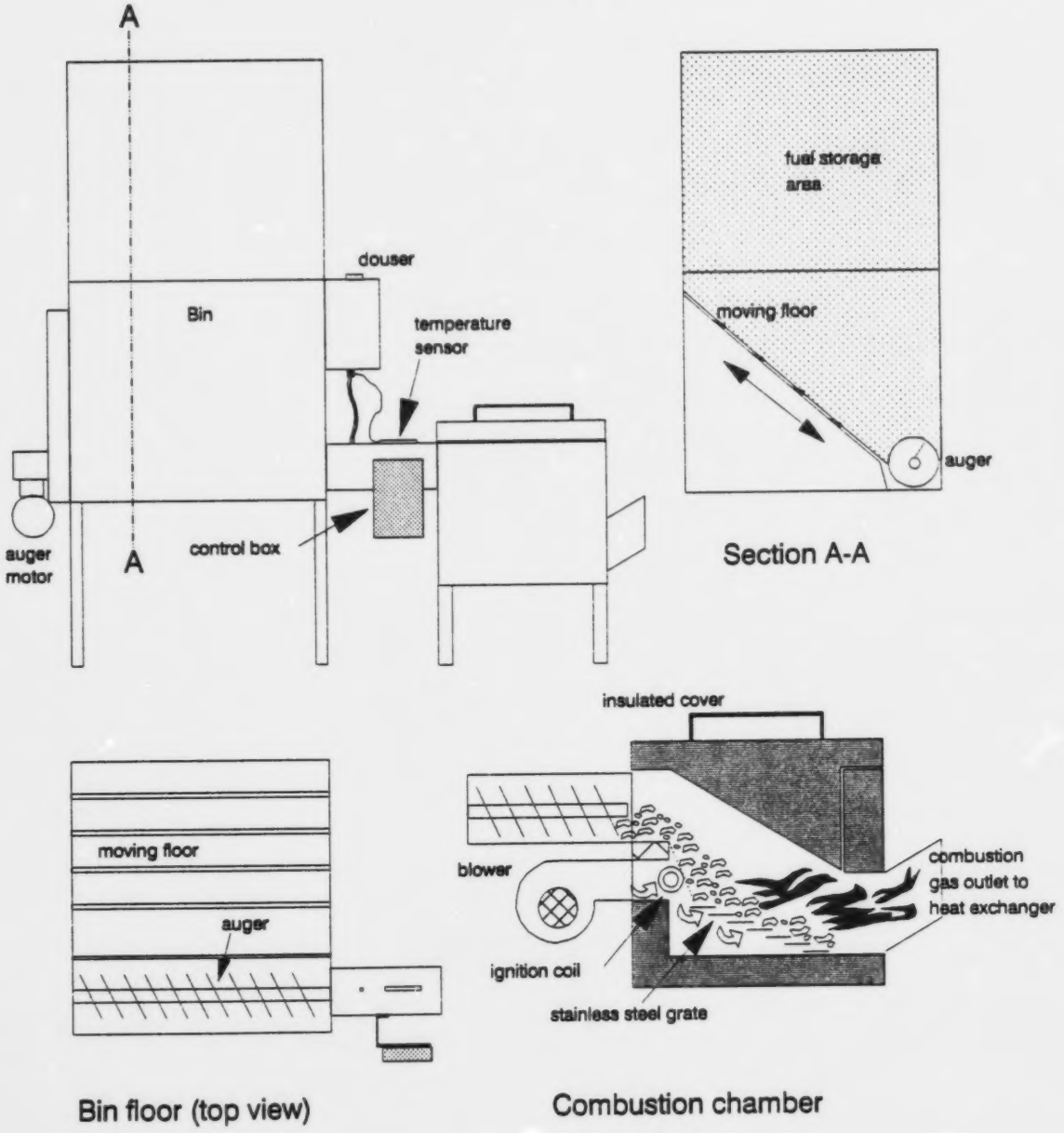
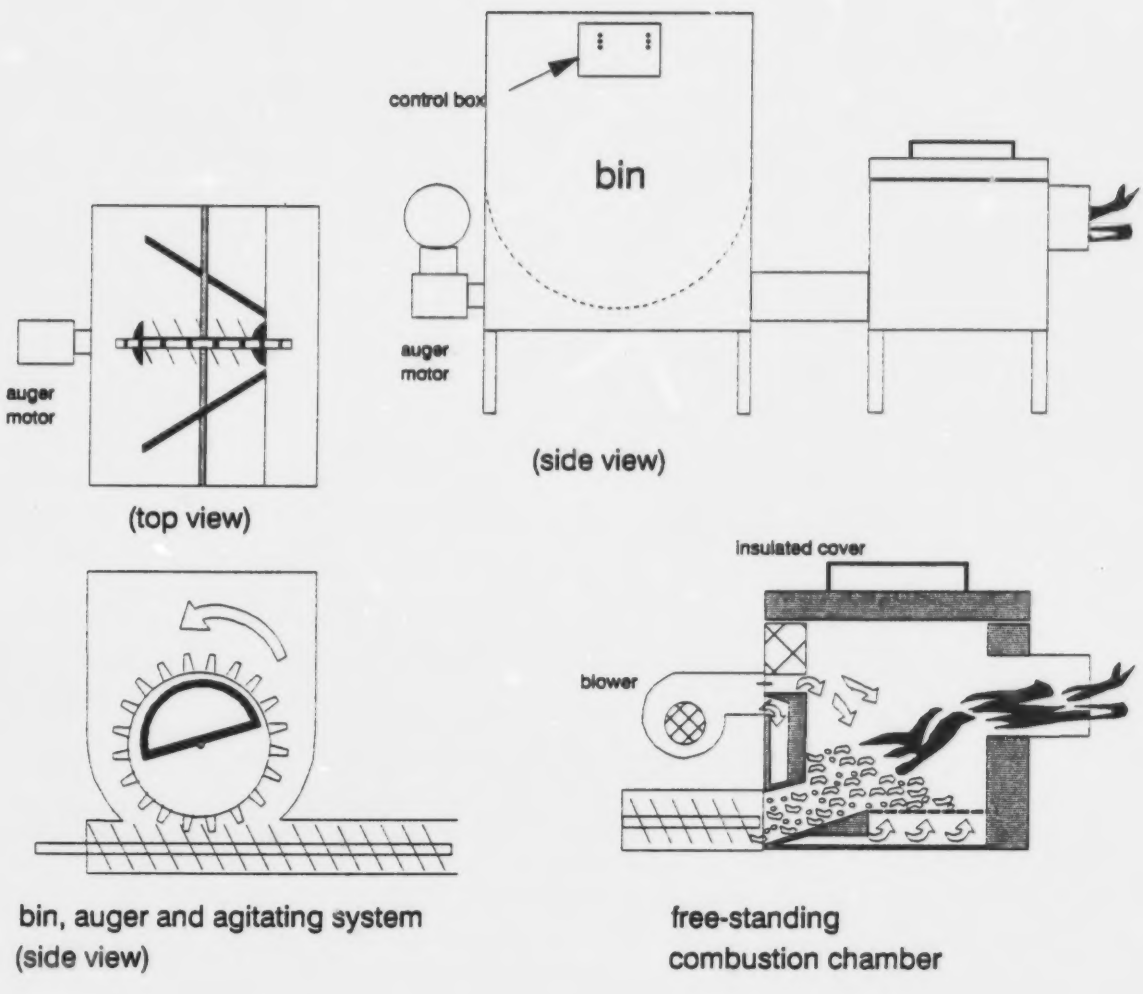


Figure 7.

Swebo pre-heater



Because a blockage is always possible, there is a need to protect the drive components from damage. Electrical components such as overheat protectors and adjustable breakers will be dealt with later. In this section, we would like to discuss the presence, location and ease of replacement of shear pins. Some units use direct drives and rely only on electrical components to prevent damage (Iwabo, Vallsta). Other units such as the TP2000 have a very visible and accessible shear pin. The auger in the Swebo is connected to the motor by a bolt. Depending on the quality of this bolt, it can be viewed as a shear pin or as a direct connection. If its nut is not properly locked in place, the bolt can come loose and it has to be replaced. In this latter case, since there is both an overheat protector on the motor and an adjustable breaker on the control panel, the shear pin could be replaced by a solid bolt which then would act only as a coupling.

Operators should be cautioned against the replacement of shear pins by more resistant materials, since this could lead to damage to the motor or to the control panel.

We have found that pelletized fuels, while slightly more expensive than chips for the equivalent heat content, provide major dividends. Because of their smaller size and uniformity, we experienced very few feed problems (ref. Appendix E). If a particulate fuel burner was to utilize only pellets, practically all its components could be downsized and power requirements greatly reduced. However, pellets have one major drawback: they must be kept dry at all times. Also, their ash content is dependent on the type of biomass used, e.g. wood, bark, cardboard, etc. The ash content of some pellets exceeds two percent, and this level may be excessive for some appliances.

d) Motor

i) Power

The feed mechanisms must be driven by a motor which is sufficiently powerful. However, brute force is not usually the best solution to ensure uninterrupted feed. As previously discussed, a motor cannot compact fuel indefinitely against a wall. After some time, either the motor will overheat, the fuel flow will block or the wall will bulge or burst. There is also a limit on the size of particles that can be transported by a particular auger. Particles can be sheared against the tube inlet edge but this is inefficient and unpredictable.

ii) Electrical protection for motor

Since most motors will eventually have to contend with a jammed auger, it is necessary to protect them against damage. Two types of protection are available: overheat protection and adjustable amperage breakers. For best coverage, it is advantageous to have both types of protection installed in the system.

The overheat protection on the motor allows the motor to function until its temperature rises above a preset limit. Motor overheat protectors are very reliable but take considerable time to cool down before a motor reset is possible.

An adjustable amperage breaker allows the motor to slightly exceed its rated current. It will trip when a preset amperage is reached. It can be rapidly reset because there is no overheating. Its function is to open the circuit before the motor or wiring overheats.

> Although these circuit breakers are usually reliable, they are not foolproof. The TP2000 50kW required rewiring through a phase shifter to convert its 3-phase-220 to single-phase-220. We were left with a lot of electrical wiring which looked very complex and which we would not attempt to troubleshoot. Later, when the stoker's auger jammed and the replacement shear pin did not break, the breaker also failed to function. The circuit overheated and components began to melt. The motor and wiring were subsequently replaced with single-phase-110.

e) Burnback prevention

i) General

Burnback is the term used to describe the situation when the fuel burns backward inside the feed system, towards the surge bin. This situation can be very dangerous should the fuel charge inside the bin ignite.

Certain conditions must be present to permit burnback:

- a continuous line of fuel from the combustion chamber to the auger and bin;
- a poorly-sealed feed system, an open bin being the worst case.

Some conditions will favour burnback more than others:

- dry fuel;
- a high-pressure fan;
- a porous fuel mixture (screened chips rather than sawdust);
- a low level of fuel in the hopper;
- a heat exchanger with a relatively high resistance to the passage of exhaust gases;[6]
- a short auger rather than a long one;
- hold-fire ignition rather than manual.

ii) Prevention or protection

To prevent burnback, manufacturers have devised a number of safety devices such as fuel breaks in the feed system and well-sealed bins. Some manufacturers have included switches in bin-cover latches; they turn off the circuitry if the cover is not shut properly. Since not all systems are designed in this manner and even these designs are not safe from carelessness, it is necessary to have a device which will extinguish the fire if a burnback occurs. The extinguishers we have used are of two types, the thermostatic valve douser and the wax-plug douser. We recommend the installation of both types on domestic systems, the wax-plug acting as a backup for the other.

- the thermostatic valve douser

The thermostatic valve has the advantage of being a proportional valve, i.e. the higher the temperature sensed, the more it will open. This also means that as it extinguishes the fire and lowers the temperature, it closes down. This type of operation is necessary when the valve is in a pressure line, as it will prevent flooding. When this valve is fitted on a water container, it will retain some fluid in reserve, should the fire re-ignite and continue its burnback. These valves can usually be purchased from plumbing supply outlets. In some occasions it may be best to connect the thermostatic valve to the house water line.

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[6]See also section 4.1.4 b) Evacuation of hot gases and text accompanying Graph 5.

A local farmhouse is heated with a TP2000 30kW stoker. The burnback prevention system includes both a thermostatic valve and a wax plug douser. Recently, a burnback happened while we were visiting the installation. The homeowner was starting the system for the season. The chips were very dry (approx. 15%). When the burnback started, the thermostatic valve poured its entire gallon of water into the feed tube without extinguishing the fire. Some water flowed into the furnace, some into the surge bin and some was evaporated by the large thermal mass of the combustor bowl. What was left had not stopped the burnback. We stopped it before it reached the wax plug douser by pulling the fuel out. We doubt whether the additional gallon of water from the wax-plug douser would have extinguished the fire.

- the wax-plug douser

The wax-plug acts as a valve on a water container. It has the advantage of being economical and easy to install. If the water container is kept full, clean and covered, it is very reliable. Since the wax-plug can only be installed with a water container (rather than being on-line) it will not be influenced by a shutdown of the pressurized water supply or a power outage on systems with well-water. This system has the disadvantage that the entire container empties into the fire as soon as the plug has melted, leaving no supply for a recurring burnback. It is ideally suited as a backup for a thermostatic valve, when placed closer to the bin, on the cooler side of the auger feed tube.

- other extinguisher types

Water is not the only type of extinguishing agent that can be used. It is possible to use powder type extinguishers or even CO_2. These other types have the advantage of not damaging the electrical components of some appliances. They have the disadvantage of being less readily available and more costly. After discharge of this type of extinguisher, the user is left without protection until it is replaced or refilled. A powder-type extinguisher has the added inconvenience of being messy to clean up.

- adjustment or positioning

Heat sensors for thermostatic valves can be adjusted for more or less sensitivity. A poorly adjusted or positioned heat sensor (or wax-plug) can cause unnecessary functioning of the douser. High output fuels might give off enough heat in normal operation to trigger the douser.

Two types of adjustment are possible: positioning the sensor further away from the heat source and/or reducing the sensor sensitivity. Most sensors can be moved away from the heat simply by loosening a retaining clamp. Some sensors have the additional convenience of being equipped with a temperature adjustment knob.

Although less sophisticated, wax-plugs also have a measure of adjustment. They can be positioned further away from the heat source or a metallic extension can be inserted in the initial hole to locate the plug a few centimetres further away from the heat source.

4.1.4 Heat-exchange section: remaining products of combustion

The heat exchanger on a stoker or pre-heater must not only provide good heat exchange area but must also have provision for the removal of the products of combustion: ash and hot gases.

a) Ash removal

i) General

Particulate fuel burners usually burn with high combustion efficiency and produce few coals or carbon particles. The fuels they utilize, however, have a minimum ash content of 0.7% for chips and more for bark and pellets. Fuels with a high content of fines will also add large quantities of carbon particles to the ash. It can be estimated that for each ton of fuel burnt, more than 7 kg (15 lb.) of ash is produced. Some of this ash will accumulate in the pre-heater's free-standing combustion chamber but most of it will end up in the furnace or boiler heat exchanger. In the case of a stoker, most of the ash will simply fall onto the floor of the furnace or boiler combustion chamber. Ash can even find its way to the stack, depending on the strength of the blower and on the size of the fines in the fuel. For these reasons, ash removal is a question with which all manufacturers and all installers must deal.

> After burning chips for a few months in the TP50 coupled to the Sherbrooke furnace, we discovered about 2 inches of ash in the furnace flue collar. Oddly enough, we have heard of a major distributor telling an installer that his pre-heater produced no ash and he did not have to incorporate provisions for ash removal!

Ash acts as an insulator on heat-exchanger surfaces and must be removed.

ii) Ash removal in stokers and pre-heaters

The design of some particulate fuel burners is such that ash is removed automatically from the burner section. On both the TP2000 stokers and the Vallsta stoker this is accomplished by the push of the incoming fuel.

On pre-heaters, ash is removed manually from the combustion chamber (eg. Swebo, Iwabo). An exception to this is in the Dan Trim pre-heater where this is done automatically by an ash removal auger.

When ash is heated to its point of fusion, it forms clinkers. If ash starts to melt in pre-heaters like the Swebo, the clinker

accumulates on top of the incoming fuel. This eventually leads to very poor combustion conditions. The moving grates on stokers like the TP50 contribute to the rapid removal of ash and clinker from the combustion zone.

iii) Ash removal in heat exchangers (furnaces and boilers)

Ash can be removed from the combustion chamber either

- through an existing ash removal door or access panel to the combustion chamber
- through the front loading door for through-the-side installations
- through the front loading door, by removal of the stoker, for through-the-door installations (not recommended).

Ash must also be removed from heat exchange surface areas because its accumulation reduces the heat exchange capacity of the appliance. Ash buildup also increases the system's resistance to combustion gas flow. This backpressure in turn increases the potential leakage of gases into the house, as indoor air pollution. The appliances (furnace or boiler) must be equipped with easily removable access covers to ash deposit areas.

The vertical tubes on the small and large Etna boilers facilitated cleaning and ash removal. Access to the tubes was easy. When brushed, the ash would fall down inside the tube to a lower ash compartment where it could be easily removed.

On one Canadian-made pellet-burning appliance, the Renfyre, the manufacturer has ingeniously simplified access for cleaning the heat-exchanger passages by installing an easy-access door similar the to loading door on a roundwood furnace.

b) Evacuation of hot gases

i) Burners without a combustion air fan

In particulate fuel burners with no combustion air fan, the evacuation of hot gases is provided by natural draft (eg. Tilley unit appliance). This natural draft also limits the burn rate of the appliance. Designing for natural draft operation is complex since large combustion air openings have to be provided as well as large grate surface areas. Natural draft systems are also limited in their choice of heat exchangers because low air-flow resistance is essential. To maintain proper draft, stack temperatures must be kept relatively high.

ii) Burners with a combustion-air fan - Fig. 6, 7)

In particulate fuel burners with a combustion air fan, the removal of hot gases should still be done by natural draft. Chimney draft should create a negative pressure in the combustion chamber. If the combustion fan pressurizes the combustion chamber, smoke may leak from loading and ash removal doors. This requires better sealing to prevent leakage. Pressurized combustion gases follow the path of least resistance, sharing the volume of gases between the available exits. The distribution of these gases obeys the same laws as electric current distribution between parallel resistances, i.e. gases are shared in proportion to reciprocal of resistance: the larger the resistance, the smaller the flow.

This explains the necessity of increasing backflow resistance (sealing of bin cover and joints). Ideally, this resistance should be so high that it will prevent all backflow, no matter what the conditions. Ideally, low resistance-to-flow heat exchangers should be used. A heat exchanger with too many flow restrictions will favour backflow of hot combustion gases instead of forward flow.

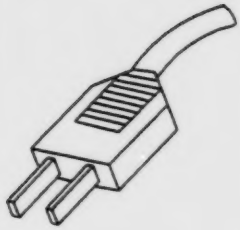
iii) General comments on the operation of units with a combustion-air fan

In many cases, after pressurized units have reached stable operating conditions, they will be under natural draft. The operator can then open the heat exchanger door without danger of flame roll-out.

Before natural draft is established in pressurized systems (i.e. while the kindling is gradually igniting, and the stack temperature is beginning to rise), smoke may escape from the appliance into the room.

4.2 Electrical components

4.2.1 General comments



a) North American vs European

Europeans have utilized stokers longer than North Americans with the result that their technology is better developed. However, the importation of European equipment causes some problems when it comes to electrical components. European electrical components meet high standards but are often a mismatch with ours. Electricians must be aware of the European colour codes for wires, e.g. the live indigo wire can easily be mistaken for our green ground wire. More importantly, our 220-volt power cabling does not match theirs. This is time consuming for electricians who have to be alert to the possibilities of improper connection. This difficulty is increased when appliance wiring diagrams are incomplete.

b) European 220-volt circuitry vs North American 220

i) Understanding basic differences

Some European 220-volt circuitry is wired for a 220-volt line on "line 1" and a neutral line on "line 2", just as for our 110-volt power lines. When we wire an appliance on 220, we expect to have a neutral line and multiple phase wiring providing the required voltage drop. This is usually attained by having two 110-volt wires come in on different phases. A European 220-volt motor would have no problem in operating on North American 220-volt circuitry.

On the other hand, when we switch the power source off, on our 110-volt lines, a single pole switch or relay will simply cut off the "live wire", leaving the neutral continuously connected. This is also the case with switches and relays in a single-phase 220-volt European circuit. When this circuit is wired to our two-phase 220-volt lines, the "neutral" part of the European circuit will be left live, with all the risks involved.

We have also found European circuits that are wired for three-phase, 220-volt current. Although this is available in industrial and large commercial applications in Canada, we seldom find it in small commercial and residential settings. Canadian distributors of stokers and pre-heaters should be conscious of this and have the appliances wired here, according to Canadian standards and practice.

From our experience with the TP50 we would not recommend going to a phase-shifter for transforming a 3-phase 220-volt system to

a single-phase 110-volt system. The user is usually left with an electrical system which he does not understand. If 3-phase power is not available, it is best to purchase an appliance which runs on single-phase or to change motors to single-phase.

ii) Wiring for safe operation

To provide proper disconnection of all power, it is necessary to install double pole switches and relays on all 220-volt lines connected to stoker circuitry, especially if some components can be accidentally grounded. A label should also be attached to remind everyone of basic colour coding differences.

We experienced a number of electrical problems in one of our installations:[7]

> Before a third control board was installed in the microprocessor, a new electrician was brought in... He found that the interlock relay was a single-pole relay that left one arm of the 220-volt circuit live at all times. In this situation, some of the parts of the circuit board remain live even when the relay switch is in the "off" position. Grounding these parts of the circuit can then result in damage to the electronic components. He also found that there was a rubber insulator missing from the back of the second control board, as well as an oversized screw which could have grounded the board and short-circuited sensitive components.

iii) Need of proper schematics

Note: the following comments must be taken in context: the appliances tested were often prototypes or one-of-a-kind in Canada and we could hardly expect manufacturers to provide all the necessary documentation in English and/or French. If these appliances were to be imported or fabricated in Canada on a regular basis, then the following would be expected to apply.

On initial installation of each appliance, we encountered a number of documentation problems with which no installer should have to contend. Some appliances did not come with installation instructions. Others had no translated instructions. Two manufacturers knowingly did not include complete schematics, claiming proprietary rights. One appliance came with faulty schematics. From our experience with these appliances, we

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[7]Installation and Operation of an Iwabo Pre-heater for the Blue Church Nursery in Prescott, Ontario. Report to EMR by I.R.T.A. August, 1988.

recommend that Canadian distributors be responsible for the following:

- All the schematics and instructions necessary for installation and maintenance should be provided with the appliance.

- These schematics should be complete, so that necessary repairs can be made without requesting information from the European manufacturer, in a foreign language. Proprietary rights to microchip programming are easily acceptable but circuit board schematics, visible to all, should not have to be reconstituted by an electrician who is trying to make a diagnosis.

- These schematics should correspond to accepted trade standards. Although welding shops have turned out acceptable stoves and furnaces, we have always demanded that their schematic diagrams of electric components be properly done. We should expect the same from manufacturers of particulate fuel burners.

- These schematics should include proper interconnection with furnace or boiler components such as limit switches, aquastats, draft dampers and oil burner controls.

- Manufacturers should be encouraged to have the electrical components of their stokers certified to Canadian standards. Better still, they should export the appliances without motors, and have appropriate Canadian motors fitted to the appliance, in Canada.

We experienced many problems and frustrations when testing the Dan Trim pre-heater because of electrical problems with its motor and with its hot-air ignition system. The automatic ignition system did not generate sufficient heat to light the fuel, and we had to light it manually. This was difficult because of the limited access to the combustion chamber.

The electrical motor which powered the auger failed on several occasions even after being repaired three times. Several of the dilution tunnel tests were ruined because motor failed to recycle. The motor was drawing a current of over 10 amperes but was incapable of restarting. After having the motor repaired the first time, we were told that the motor's start capacitators were defective.

Again the auger motor failed to recycle. The motor was repaired and it seemed that it was now a relay problem. The relays were being burnt out. The motor was again repaired and diagnosed as a relay problem. The serviceman gave no more guarantees with the latest repairs and indicated that he would not attempt more repairs without having the European parts. After the third repair the motor failed again. We believe that the motor was not designed for repeated cycling.

iv) Control box components and wiring

- Availability of components

European components for particulate fuel burner control panels and circuit boards should be readily available in Canada. No type of heating appliance will survive the Canadian market if it takes a month to replace a part each time something goes wrong. Up to now, this has been our experience with most of the stokers we have used and with many of those we have seen used by others. Many installations have not been properly monitored during their first winter of operation because by the time the appliance was de-bugged and faulty parts replaced, the heating season was over.

- Position of control boxes

Permanently-fixed control boxes should be positioned in locations where they will not overheat. Electronic components and plastics can be easily damaged if overheated. It is our opinion that the control boxes on the Iwabo and Vallsta are placed too close to the combustion chambers and risk overheating. They are also in an awkward position when it comes to adjusting the control settings or moving the appliances around. Controls should also be protected from

mechanical damage during shipment, normal operation, and servicing. They should also be easily accessible for normal operation, removal and repair.

Movable control boxes should be wired with a generous length of flexible lead. The cable length should allow normal movement of the components without the need to disconnect wires. They should also allow for positioning of the controls on a nearby wall or post. Since the appliances are often placed in a rough environment, the wiring should be of superior quality such as rubber-covered BX. The minuscule dip switches used in the control boxes of the Vallsta and Iwabo are not practical. They are too small. These appliances are often used in a harsh environment where the delicate treatment required for dip-switch manipulation is not available.

- Home-wired board

Home-wired boards should be avoided. All stokers should be provided with a properly wired board that eliminates the necessity for the installer to piece together a circuit board. All that should be left to the installing electrician should be the attachment of components on well-labelled connectors:

- power from the line,
- control components from the furnace or boiler,
- building thermostat.
- alarm system

4.2.2 Electrical controls

a) General

On roundwood-burning furnaces the building thermostat regulates the fuel burn cycle; the fan limit control thermostat controls the operation of the circulation fan. The safety-limit control is wired to stop the burn cycle should excessive temperature be reached in the plenum.

On roundwood-burning boilers the building thermostat starts and stops the circulator pump; the aquastat regulates the fuel burn cycle. The high-temperature limit switch on the aquastat is wired to stop the burn cycle should an excessive water temperature be reached.

Some stoker and pre-heater systems make it possible to alternatively use either roundwood or particulate fuels. It is necessary to prevent both from firing at the same time so as not to overheat the heat exchanger. This must be done by installing an interlock circuitry like those used on wood-oil combination or add-on furnaces. These installations need double thermostats to control their operation.

It is also undesirable to permit both roundwood and chip air-controls to operate together because large amounts of excess air are being fed from both the furnace damper and the combustion air fan. While this is generally true, some unit appliances are designed to burn both chips and roundwood simultaneously, for example, the American-made Eshland burners.

b) Controlling fuel feed, and feed rate

i) Some burners have a manual override on the feed system, to be used when lighting the fire (Swebo): the push-button switch (on-when-pushed) allows the feeder to be operated independently of the other components.

ii) Batch feed vs continuous feed

With batch-fed particulate fuel appliances (eg. Tilley) the fuel is supplied in batches to a bottom-burning combustion chamber. Fuel feed may be controlled by a photocell positioned on top of the fire chamber that monitors the presence of flames on top of the fuel. Flame is detected only when most of the fuel is burned away. Then the photocell energizes to deliver more fuel. The fuel feed is regulated by a timer. An overfill paddle (a limit switch) prevents too much fuel from being dumped in the combustion chamber. Other particulate-fuelled appliances rely on infra-red level detectors or sonic detectors.

Continuous-feed appliances supply a controlled quantity of a particulate fuel to the combustion chamber as long as there is a call for heat. Continuous-feed particulate fuel burners operate best if they are provided with a proper fuel-air mixture. This mixture can be attained by adjustments to the fan and the fuel feed. Some appliances provide several fixed feed rates (e.g. the Iwabo and the Vallsta can be set to feed continuously or for 80 or 50% of the continuous cycle).
These feed adjustments are electrical on the Swebo and Dan Trim, and mechanical on the TP2000.

All appliances should be equipped to detect overfill. Some appliances accomplish this with an overfill paddle. A photocell can perform the same function.

> Disastrous things can happen when an appliance does not have this protection. On one occasion when the TP50 lost its fire, it kept on feeding chips into the heat exchanger. The shear pin did not break and its amperage protection breaker did not jump immediately. Chips filled the heat-exchanger to which it was coupled. It pulled the bolted adapter plate apart and pushed the stoker back six inches from its furnace heat exchanger. This incredible force could damage either appliance.

iii) Hold-fire: Appliances without an ignition coil require a method of holding their fire between demands for heat. This is achieved by the hold-fire mode. In this mode, the auger feeds fuel to the combustion area on a controllable, intermittent basis. With some appliances we have found that these hold-fire modes consume considerable quantities of fuel when on stand by over long periods of time.

More sophisticated appliances also provide fan adjustments for this hold-fire mode: on the Swebo, the fan can be adjusted to continue a pre-determined length of time after the feed has stopped. This consumes the remaining fuel and prevents excessive smouldering.

c) Controlling air (under-fire and over-fire)

i) Need for a manual override on some stokers

On certain appliances it would be useful to be able to operate the fan without operating the fuel feed system. In some cases this would facilitate the ignition procedure. It would also facilitate burning surplus fuel from the combustion chamber without the continued feed of new fuel. This manual override to activate the fan should be controlled by a push button switch. None of the appliances we tested had such a control.

ii) Variable-output fans

Two main types of controls exist on combustion air fans for these appliances. Variable-speed fans (e.g. Swebo) regulate air by adjusting the fan's rpm. Fixed-speed fans utilize an adjustable air damper to limit the amount of air intake.

iii) Under-fire and over-fire air controls

Some appliances provide a means of varying the distribution of combustion air between over-fire air and under-fire air (Swebo, Dan Trim, Iwabo). This allows for fine tuning of the appliance to a particular fuel. Some compact fuels need high under-fire air pressure for primary combustion whereas fuels like screened chips need much less under-fire air for primary combustion.

5.0 B415 TEST RESULTS

This section presents a general summary of the project's overall findings. It gives the "performance and emission" levels of particulate fuel burning systems and shows how these are dependent on the type of stoker or pre-heater, the heat exchanger, burn rate, fuel type and fuel preparation. The purpose of this section is to show how each of these variables affects performance, and not to comment on individual test results.

5.1 Efficiency

The efficiency of each appliance combination is the percentage of energy which is extracted from the fuel energy input. Simply stated it is the ratio of heat output/energy input. The CSA B415 calculations are meant to calculate this ratio. In fact, the test procedure measures the chemical constituents and temperatures of the gases that are discharged into the chimney flue, converts these data into the equivalent amount of heat, and subtracts this quantity from the heat-equivalent of the fuel input, to estimate the useful heat output of the system.

We are wary when calculating efficiency of particulate fuel burners with the B415 method because we are not confident that we can measure parameters to the accuracy required by the calculations[8]. For example, because of system size, the heat input is measured from feed tests prior to the testing. During actual B415 testing we can only assume that the appliance is feeding at the same rate. If the actual feed rate during the B415 test is inferior to the feed-test-rate, the heat input is overestimated; this decreases the calculated efficiency. Many other factors can produce similar shifts.

Efficiency results calculated from the B415 standard are given in Graph 1. We believe the TP2000 30 kW results and those of the other burners should be closer together.

As can be seen from Figure 8[9], emissions reduce the possible useful heat output by reducing the amount of heat generated by combustion. Reducing emissions in a given system will increase its energy efficiency. The relative efficiency of two systems with identical emissions is dependent on the efficiency of their heat exchangers, i.e. the efficiency of the appliance is a function of heat exchanger efficiency, as shown in examples 3 and 4 of Figure 8.

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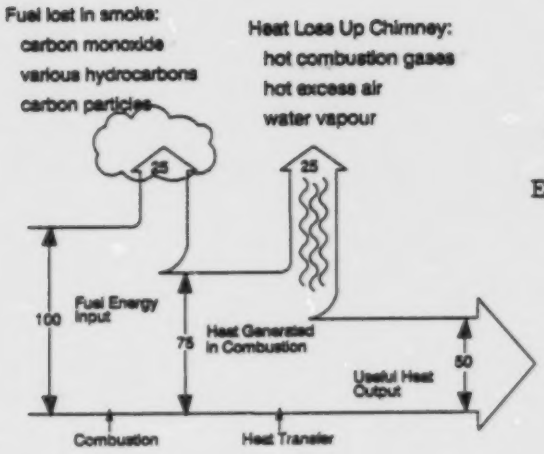
[8]Ref. Sensitivity Study of Traditional Flue Loss Methods for Determining Efficiencies of Solid Fuel Heaters. Shelton, Graeser and Jaasma; Shelton Research, Inc. Publication, 1984.

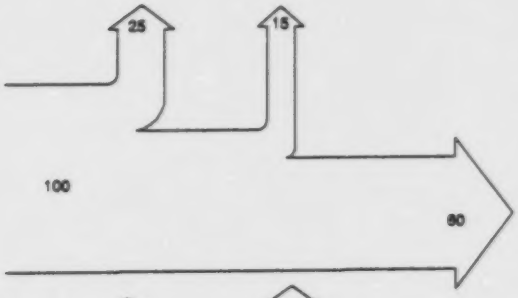
[9]Ref. Solid Fuels Encyclopedia. Shelton, Jay; Garden Way, 1983.

Figure 8.

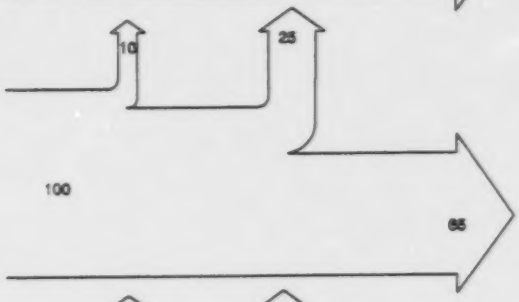
Efficiency



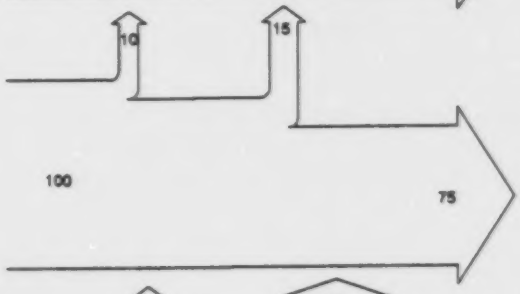
Example 1.
High Emissions,
Poor Heat Transfer



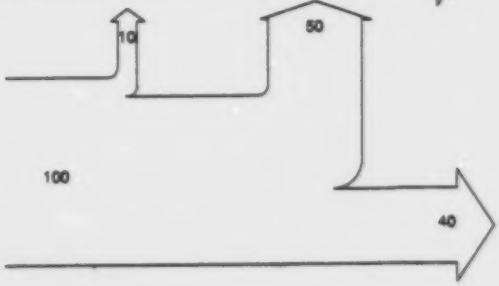
Example 2.
High Emissions,
Good Heat Transfer



Example 3.
Low Emissions,
Poor Heat Transfer

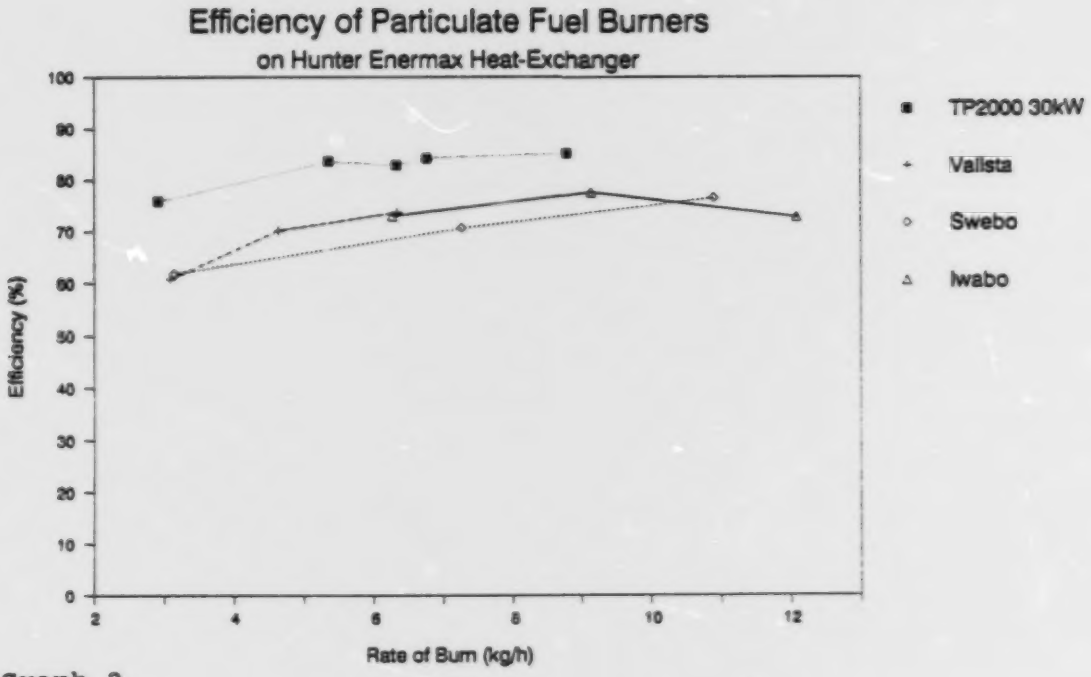


Example 4.
Low Emissions,
Good Heat Transfer

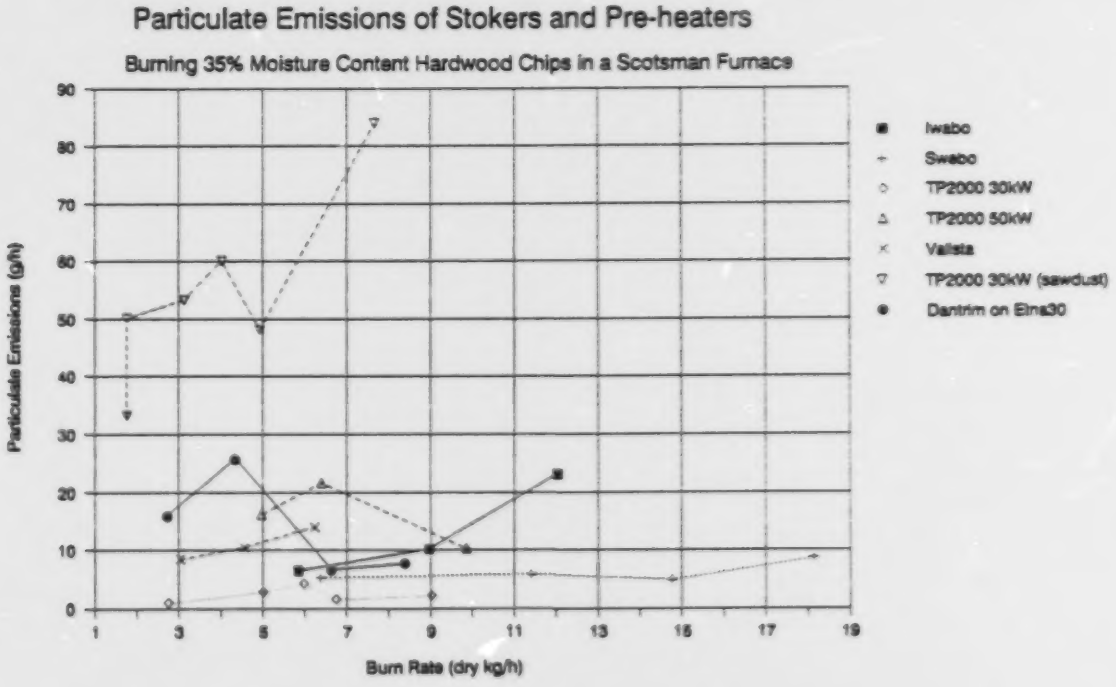


Example 5.
Low Emissions,
Very Poor Heat Transfer
Therefore Low Efficiency

Graph 1



Graph 2



5.2 Emissions

5.2.1. Stokers vs pre-heaters (Graph 2)

Most particulate fuel appliances burn cleanly with sawmill chips. The emissions from several of these are below the EPA limits[10].

Other conclusions can be drawn from Graph 2. Emission levels indicate that pre-heaters (Swebo, Iwabo) burn cleaner than stokers (TP50, Vallsta) with sawmill chips. The smaller, enclosed combustion chambers on pre-heaters provide a hotter combustion environment than the open stoker bowls sitting inside a large, often uninsulated furnace. The TP30, although classified as a stoker, has an enclosed combustion tube. This tube acts much the same as the independent combustion chamber on pre-heaters and gives similar results.

From the above data, we can conclude that, at least for wood chips, it is better to have an enclosed combustion chamber than an open combustion bowl. The closed combustion chambers on the TP30 and on the Swebo produce low emissions. The open combustion bowls on the TP50 and the Vallsta produce higher emissions.

Emissions levels for a TP30 burning sawdust (49% mc) have been added on this graph as a comparison. These levels are typical of emissions from most compact, moist fuels such as whole-tree chips and ground bark. Perhaps the most remarkable information on Graph 2 is the fact that emissions from the Swebo remained below the EPA limits until the burn rate increased beyond the 16 kg/h (approximately 200,000 Btu/h). This is equivalent to the combined burn rate of approximately 6 to 8 "average" stoves.

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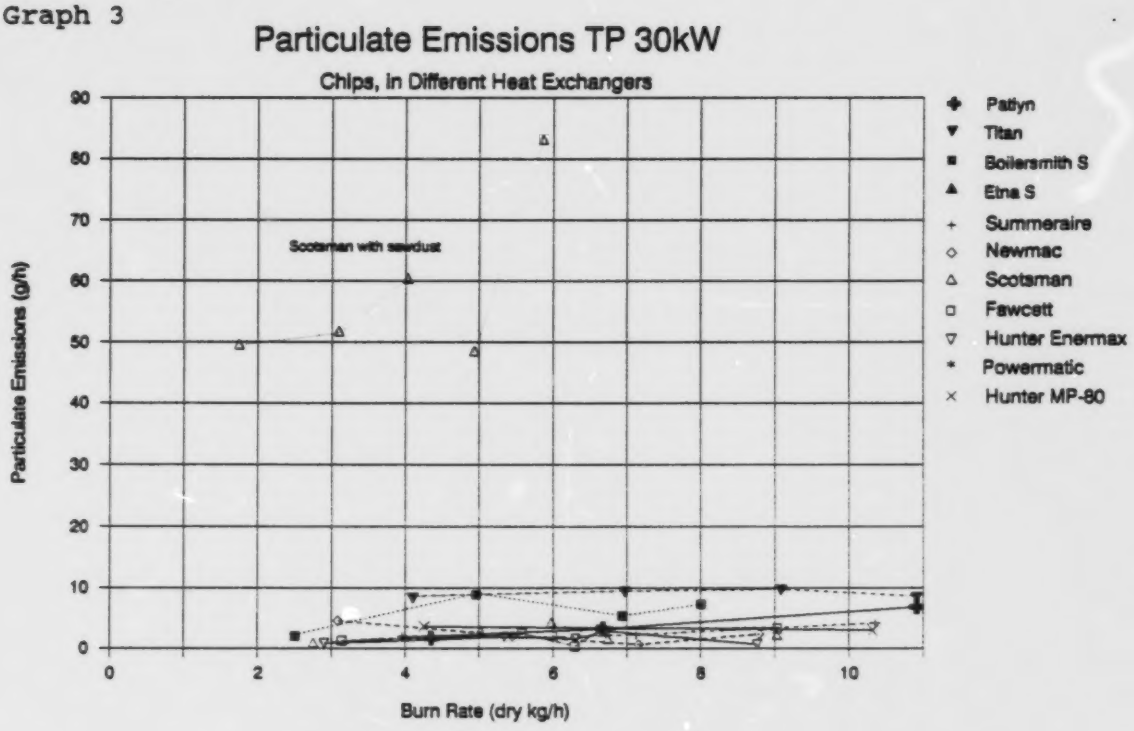
[10]Emission test results are given in grams of particulates per hour. It is a time-weighted average. We refer to the United States Environmental Protection Agency (EPA) 1988 maximum limit of 8.5 g/h of particulate emissions for non-catalytic woodstoves, for comparison purposes.

Graph 3



5.2.2 How heat exchangers influence emissions (Graph 3)

Emissions from the TP2000 30 kW stoker are only slightly influenced by the type of heat exchanger used when burning hardwood chips at 35% mc The TP30 emission levels are low with all heat exchanger types although we note a small increase in emissions with two boilers, the Titan and the small Boilersmith. For comparison, we have included emissions from the combustion of sawdust at 49% mc in the Scotsman.[11]

We have shown that pre-heaters tend to have a cleaner burn than stokers. Pre-heaters have more control over the environment in which combustion takes place. This makes them less dependent on the type of heat exchanger. On the other hand, stoker combustion takes place within the heat exchanger and this makes the stoker more dependent on the heat exchanger than the pre-heater. This influences the choice of heat exchangers for stokers. The area where the flames enter the firebox must be small and insulated. Large cold fireboxes will need relining, much as would be done for oil heaters.

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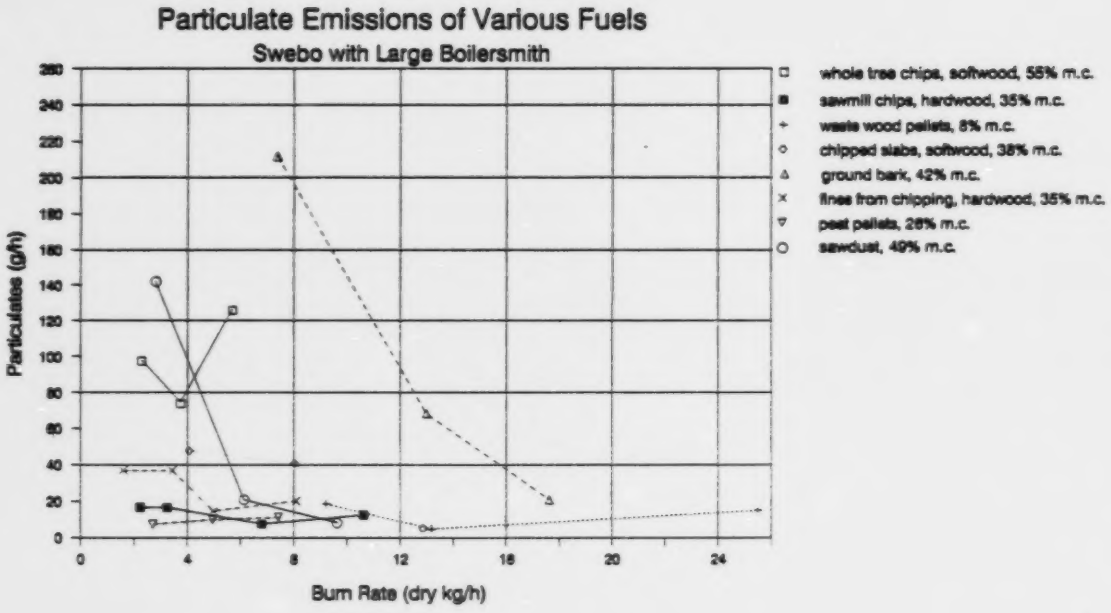
[11]The TP30 emission levels with sawdust are shown to increase substantially over 5 kg/h. Above this rate, fuel is not completely burned and emissions rise quickly.

Other test data has shown that the TP30 and Vallsta have lower emission levels when used with the small Etna rather than with the small Boilersmith. While both heat exchangers have large uninsulated fireboxes we believe the path of exiting gases in the Etna is much more turbulent than in the small Boilersmith. This turbulence enhances mixing and more complete combustion. When the Swebo and Iwabo were used with the large Etna and large Boilersmith we found no noticeable difference in emission levels.

Graph 4



5.2.3. How fuels influence emissions (Graph 4)

In this study we burned eight different fuels in a Swebo pre-heater coupled to a large Boilersmith boiler. Emission levels vary considerably with fuel type and with burn rate.

Sawmill chips, waste wood pellets and peat pellets burn with fairly low particulate emissions over a wide range of burn rates.[12] Emissions from peat pellets were low but still appeared as black smoke, even at this low level. This might be caused by a high proportion of carbon particles in the flue gas.

Emission levels from whole tree-chips, sawdust, ground bark and fines from chipping are high. They are all compact fuels. Finer particles fill in the voids between larger pieces. Combustion under-fire air cannot be fed through the fuel but is restricted to the edges of the pile. To compensate for the poor burn, more excess air must be supplied to the poorly-burning fuel.

These compact fuels also can have a higher moisture content than the wood from which they originated. If exposed to rain, they soak

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[12]Note: the EPA particulate emissions limit for woodstoves is only 8.5 g/h. If the stove output is 30,000 Btu/h, the fuel input would be about 2.5 kg/h.

up water easily. This high moisture content also tends to raise emission levels caused by fuel compactness.

At higher burn rates it is interesting to note that both sawdust and ground bark can burn with much lower emissions levels. Only at these higher feed rates does the Swebo's combustion chamber reach high enough temperatures to maintain proper combustion. Each of these fuels was fed until the maximum burn rate was reached. Past these maximum burn rates (feed rates), more fuel was being supplied to the combustion chamber than it was possible to burn. The combustion then became oxygen-starved. For example, in Graph 3 sawdust reaches its maximum sustainable rate at 5 kg/h (11 lb/h) on the TP30. Above this rate fuel is not completely burned and emissions rise quickly. Although this cut-off point is appliance-dependent (stoker/heat-exchanger, pre-heater/heat-exchanger), it is also clearly fuel dependent.

5.2.4. How moisture content influences emissions (Graphs 5a and 5b)

A fuel's moisture content influences its combustion characteristics. This can be clearly seen from Graphs 5a and 5b. In these graphs each line represents one batch of fuel that is fed at 3 different feed rates. Clean combustion (Graph 5b) is lost somewhere between 40 and 50% mc As moisture content of the fuel increases, heat production is reduced. This reduction is first due to an increase in the amount of energy necessary for evaporation of water. This reduction is compounded by the decrease in combustion efficiency at high moisture contents (Graph 5b). In simpler terms, we have more water to boil and less fuel to make it boil, because some of the fuel is going up in smoke. These observations apply strictly to variations in moisture content in hardwood chips burned in the Swebo pre-heater. Other pre-heaters may behave similarly at similar moisture contents.

Both graphs reveal that a radical change happens somewhere between 40 and 50% mc but it is hard to pinpoint the exact position of the break point. This part of the testing was carried out in the summer months. At these high moisture contents the wood started to deteriorate.[13] It became difficult to distinguish between losses due to moisture and losses due to deterioration of the wood itself. In any case, this becomes a theoretical question because most of the very moist particulate fuels found in the field also deteriorate rapidly.

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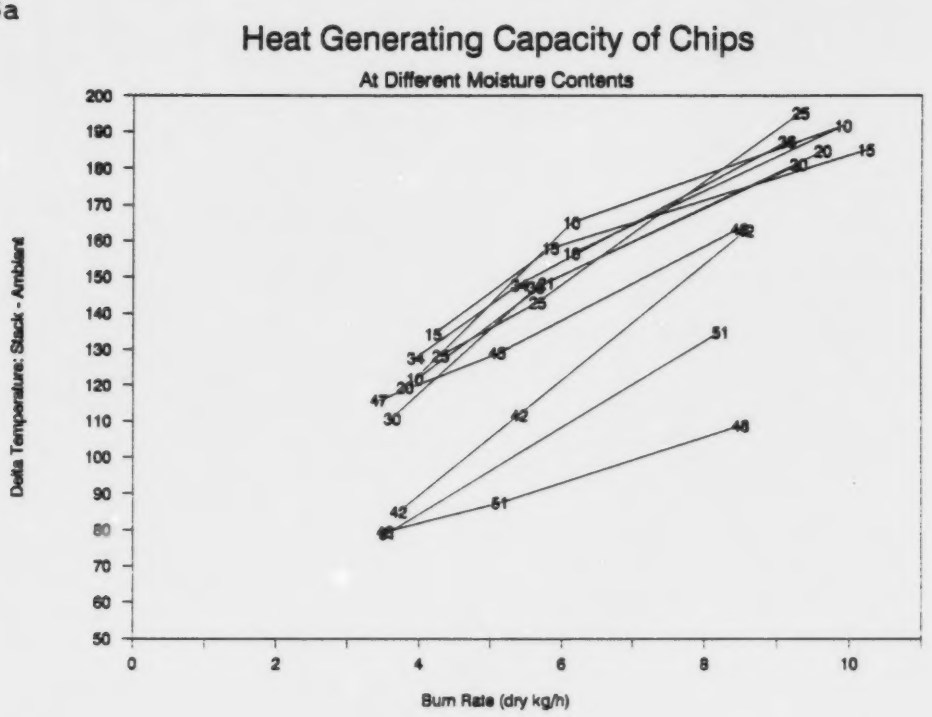
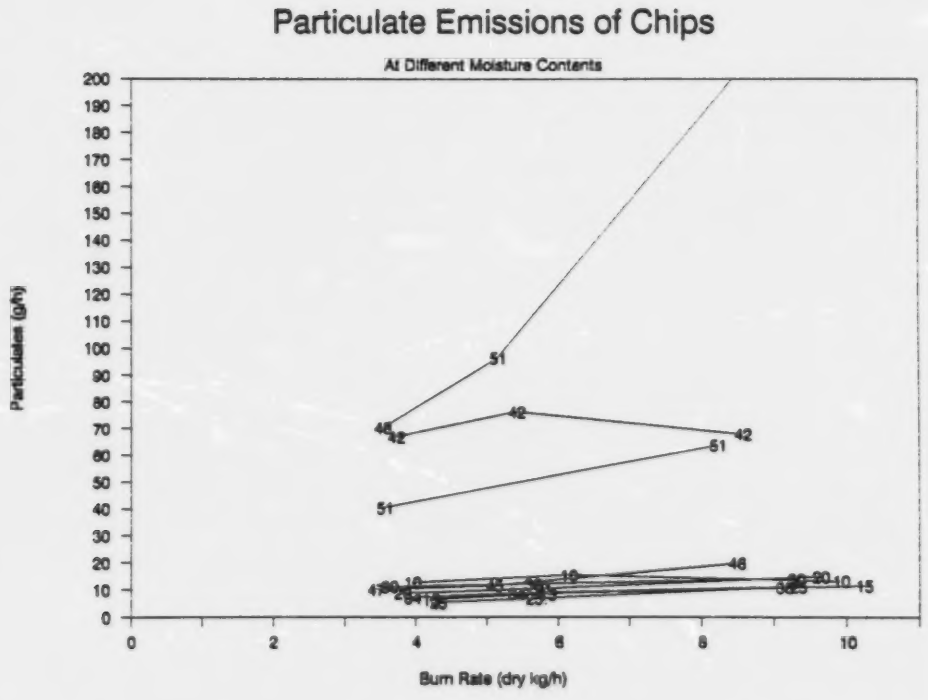
[13]Some batches of fuel with lower moisture contents had deteriorated more than other batches at higher moisture contents. This may partly explain the absence of a clear demarcation line between batches: a good example are the two emission points (Graph 5b) from the batch at 51% (3rd from the top) and the three emission points from the batch at 42% (2nd from the top).

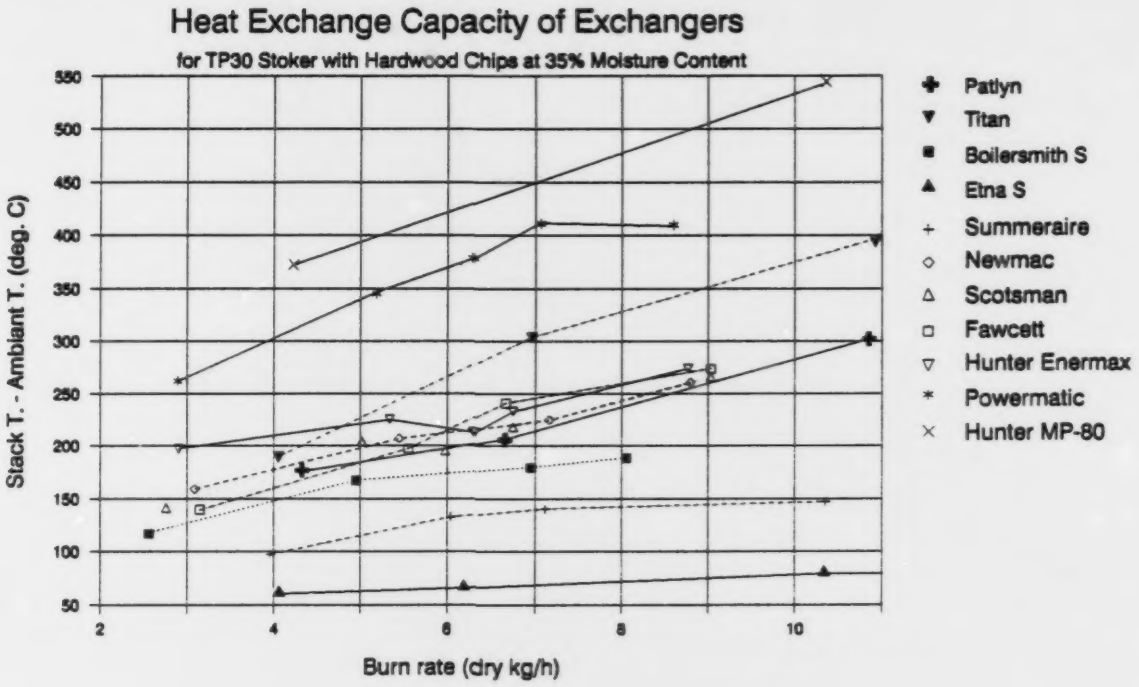
Graph 5a



Graph 5b



Graph 6



5.3. Heat Exchange Characteristics

5.3.1. Heat exchange capacity of heat exchangers (Graph 6)

Two important characteristics influence the choice of a heat exchanger for a particulate fuel burner. We want an appliance that will efficiently extract heat from the flue gases and that will not hinder their passage. We can obtain information on both of these characteristics from Graph 6.

Efficient heat exchange is demonstrated by low stack temperatures. However, excessively low stack temperatures will lower draft and cause problems on all systems, especially those that operate without forced combustion air. The small Etna boiler, the Summeraire furnace and the small Boilersmith boiler provide the highest heat exchange for the TP30. The small Etna is recommended by several manufacturers of particulate burning systems. However, it lowered temperatures below 100°C, and therefore it would not be recommended for use with the TP30 unless this situation could be corrected under actual operating conditions.

In the Etna boiler the flue gases leave low at the rear of the combustion chamber, travel up to the top of the boiler, then down and up again through the vertical tubes to exit the boiler. This extended path is responsible for the boiler's very high heat

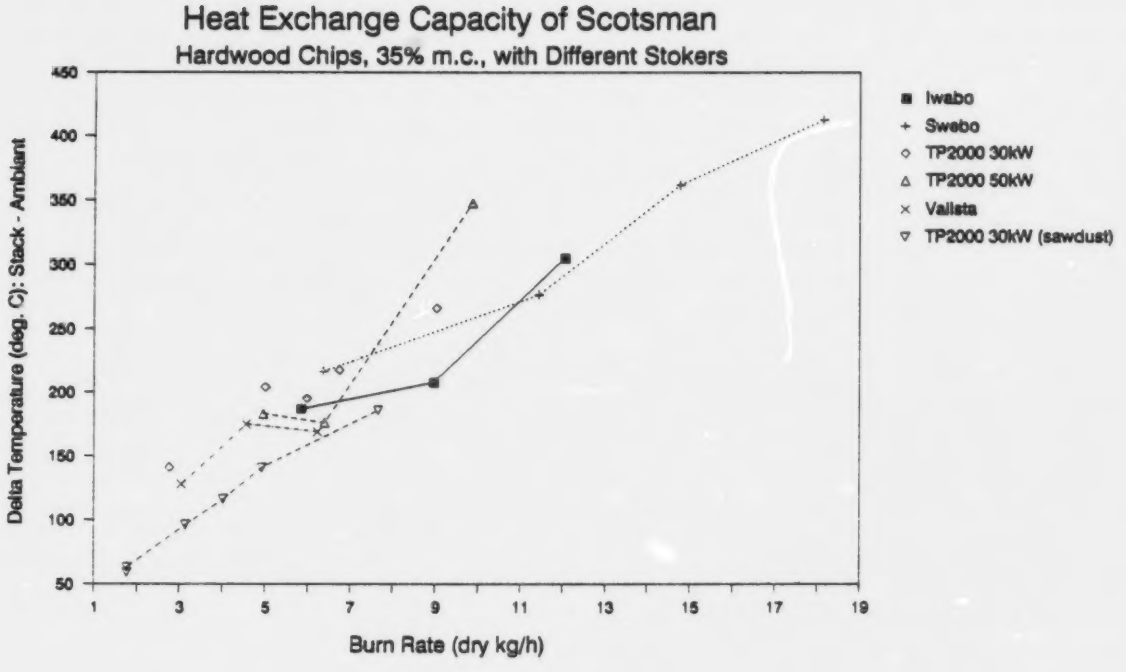
exchange rate. In the small Boilersmith the path which the gases follow is shorter and hence heat exchange is less. Other test data with the Vallsta stoker confirms this pattern, although it is not as pronounced. In other testing with the Swebo the large Etna has shown to achieve the same heat exchange as the large Boilersmith while it is only half its weight. The Etna's design provides a much more efficient heat exchange path.

The Summeraire furnace is so efficient as a heat exchanger for this size of stoker that it should only be connected to an insulated chimney (to avoid condensation of flue gases).

The Hunter MP-80 and the Powermatic furnaces are examples of undersized heat exchangers for the TP30. They would be poor choices for stokers and pre-heaters operating in the range of the TP30 or above.

A good heat exchanger is also characterized by a low resistance to combustion gas flow. Resistance can be compared by observing the point furthest to the right for each heat exchanger. This reveals that none of the heat exchangers offered excessive resistance for burn rates under 8 kg/h (18 lb/h). The very high heat exchange capacity of the small Etna boiler does not hinder the passage of gases. This makes it an ideal exchanger for higher-capacity particulate burners. The large Etna showed no more resistance to gas flow than the large Boilersmith when fired at burn rates of 15 kg/h (33 lb/h). This also makes it an excellent heat exchanger.

Graph 7

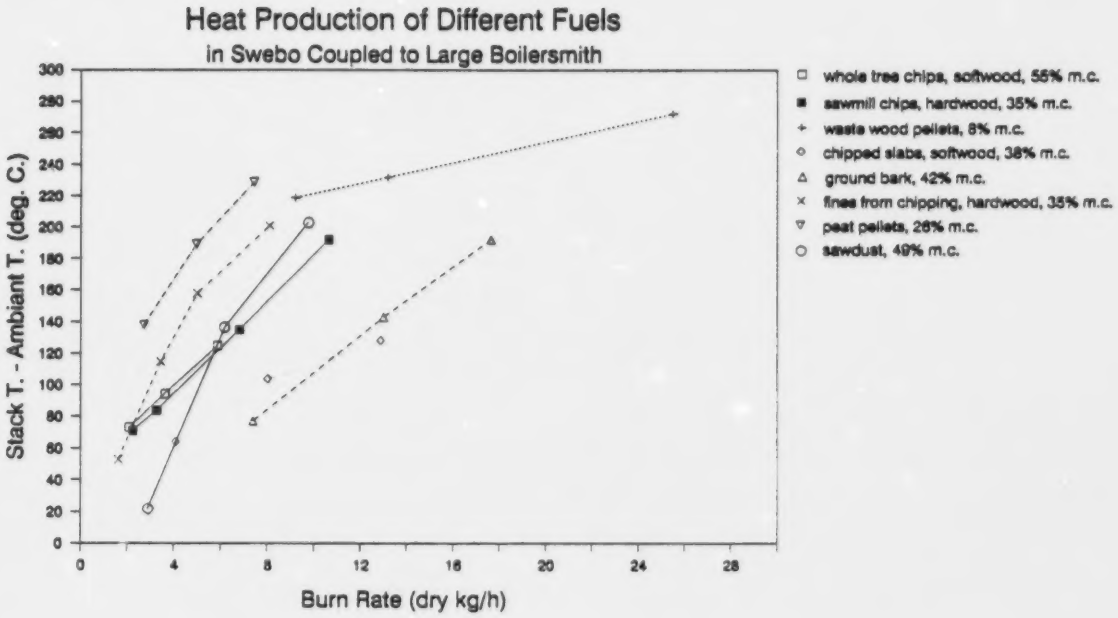


5.3.2. The influence of the combustion appliance on stack temperatures (Graph 7)

A linear relationship exists between stack temperature and the rate of burn of a fuel on a given appliance combination. Incomplete combustion of the fuel in a particular burner lowers the quantity of heat produced by that fuel. We can note some of these differences with the help of Graph 2.

In general the combustion appliances with the highest stack temperatures on Graph 7 will have the lowest emission levels (Graph 2). If we look at the appliances with the lowest emissions in Graph 2, the TP30 and the Swebo both burning chips, we notice that they also produce the highest stack temperatures. Conversely the TP30 with sawdust, and the TP50 and Iwabo with chips, have higher emissions (Graph 2) and lower stack temperatures (Graph 7). To put it simply, the particulates represent incompletely burned material. If the system could burn them, temperatures would go up and emissions would go down.

Graph 8


Heat Production of Different Fuels
in Swebo Coupled to Large Boilersmith
Stack T. - Ambiant T. (deg. C.)
Burn Rate (dry kg/h)
whole tree chips, softwood, 55% m.c.
sawmill chips, hardwood, 35% m.c.
waste wood pellets, 8% m.c.
chipped slabs, softwood, 38% m.c.
ground bark, 42% m.c.
fines from chipping, hardwood, 35% m.c.
peat pellets, 26% m.c.
sawdust, 49% m.c.

5.3.3. Heat production of different fuels (Graph 8)

The heat available (lower heat content) from various fuels can be evaluated from the stack temperatures in a given appliance combination. Graph 8 reveals that peat pellets and waste wood pellets have the highest heat content while ground bark and the chips from slabs have the lowest.[14]

Differences in stack temperatures may be due to a different higher heat content of a fuel and/or to its lower moisture content. Fuel processing can easily influence the latter. Pelletizing, for example, removes large amounts of water from the fuel. Waste wood pellets are often made of ground bark. Pelletizing reduces the moisture content of the bark. Unprotected piles of ground bark soak up large quantities of water. This shows up on this graph as a radical difference in effective heat production from these fuels.

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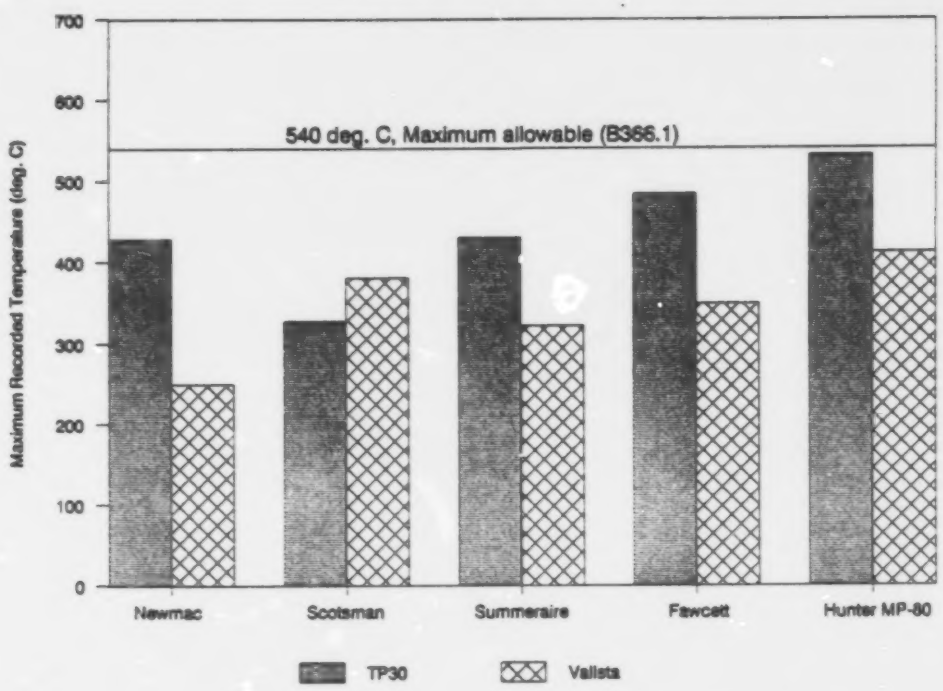
[14]Tests conducted with chips from slabs should not be considered as conclusive. The chips were of poor quality and were contaminated with sand and gravel. The pieces were non-uniform with many long slivers. 4.4 kg of sand, gravel and stones were fed into the Swebo's combustion bowl after burning only 60 kg of these chips.

It should be stressed that high heat content fuels might produce overheating in appliances that otherwise function well with "average" fuels such as sawmill chips.

Graph 9



5.4 High-fire testing

All temperatures recorded during high fire tests fall below the maximum allowable limit of 540°C permitted by B366.1. Graph 9 shows a representative sample of maximum temperatures obtained on 5 different heat exchangers when fired with both the TP30 and the Vallsta stokers.

Maximum temperatures may have occurred at either the side, top or rear surfaces of the heat exchanger. These highest values were recorded when the stokers operated at their maximum outputs. Hardwood chips at 35% moisture content were used. Drier chips or wood pellets would probably have given higher temperatures. Therefore, slightly larger heat exchangers should be chosen if the appliance is meant for these fuels.

Maximum temperatures registered on the surfaces of the boilers were lower than those on furnaces. This is understandable as the boiler surfaces are cooled by a water jacket.

We exceeded the 540°C maximum temperature limit by some 200 degrees on one of the heat exchangers by simply insulating the exterior of its combustion chamber. This was initiated from a previous study with a wood furnace burning roundwood. Insulating its single-wall, steel combustion chamber was found to lower particulate emission

levels. A word of caution to manufacturers: insulating steel liners from the outside might cause overheating of the steel, i.e. the use of exterior insulation might necessitate the use of a different grade of steel.

6.0 COST-BENEFIT ANALYSES

Cost-benefit analyses were performed for particulate fuel burning systems to determine the payback. Their costs were compared with those of oil heating, using oil costs of 32.9 and 42.9 cents per litre. The payback period was calculated on the basis of three variables: stoker or pre-heater power output, system efficiency, and hours of operation. Each of these variables was changed while the other two were kept fixed. This was done for three different installations with initial system costs of $5,000, $10,000 and $15,000. Results are illustrated in Graphs 10a, b, c and 11a, b, c.

6.1 Payback based on oil cost of 32.9 cents per litre

When maximum power output is used as a variable (efficiency remains fixed at 70%, and hours of operation fixed at 1500/year), Graph 10a shows rather naturally that the payback period decreases as the power output increases. As maximum power output approaches 70 kW, as we would find in small-commercial systems costing less than $10,000, there is a payback period of 5 to 6 years.

When annual hours of operation is used as a variable (efficiency remains fixed at 70% and power output fixed at 60 kW) Graph 10b shows that the payback period decreases as the system's yearly hours of operation increase.

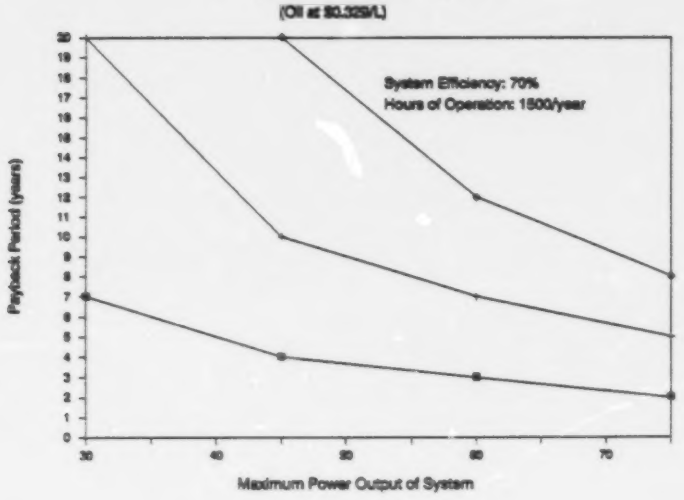
When efficiency is used as a variable (power output fixed at 60 kW, and hours of operation fixed at 1500/year), Graph 10c shows that the payback period decreases as the system efficiency increases. An increase in efficiency from 50 to 70% in a $10,000 system decreases the payback period from 12 years to 7 years.

6.2 Payback based on oil cost of 42.9 cents per litre

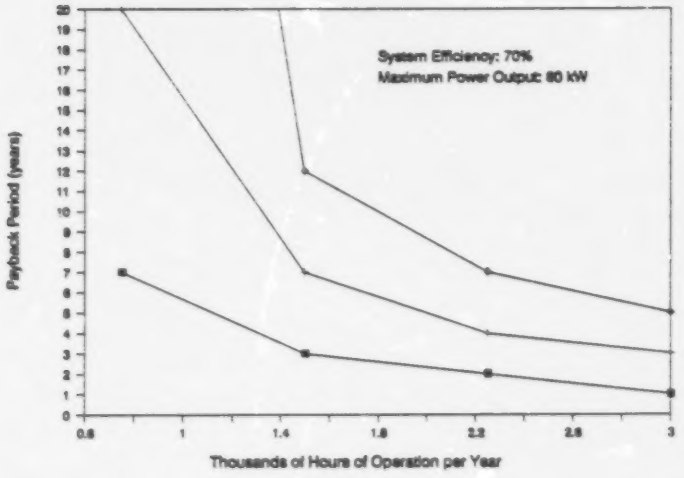
As heating oil prices increase, biomass heating become more interesting. For communities in Northern Canada where oil is 10 to 30¢ higher than in Ottawa, payback periods become much shorter as can be seen from Graphs 11a, b and c.

As of January 1989, a 130 kW system is being manufactured and installed in P.E.I., using private capital only, with 90 percent Canadian content. The pre-heater selling price is about 65 percent of the delivered cost of a similar Swedish appliance. This is the bottom line.

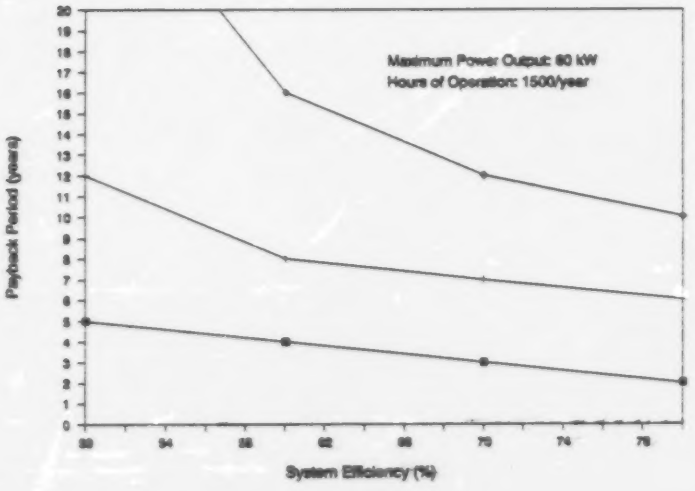
Payback Analysis



Graph 10a



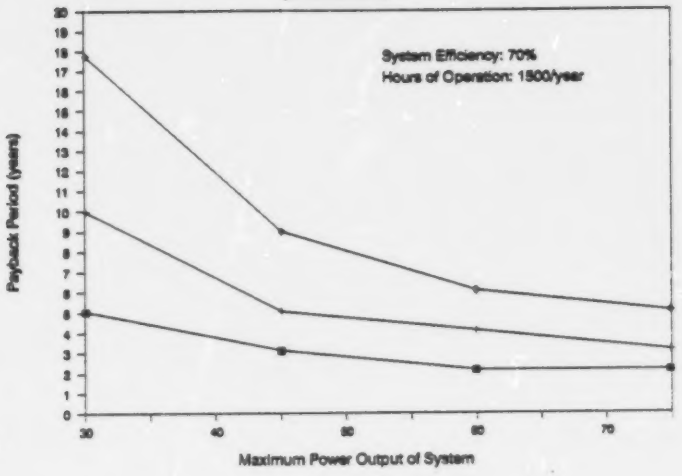
Graph 10b



Graph 10c

Payback Analysis

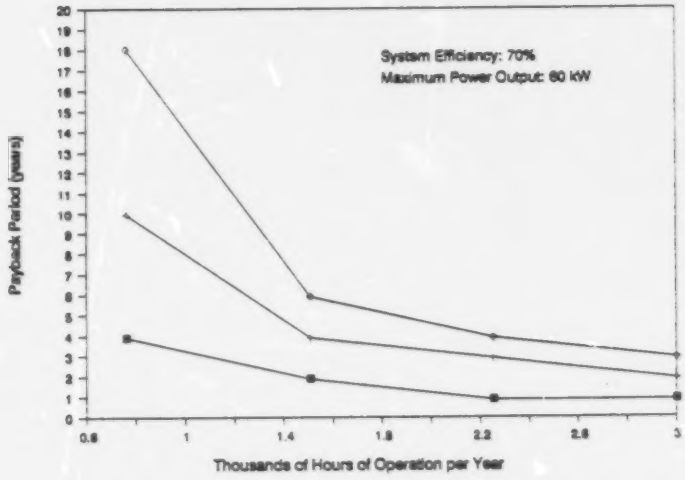
(Oil at $0.429/L)



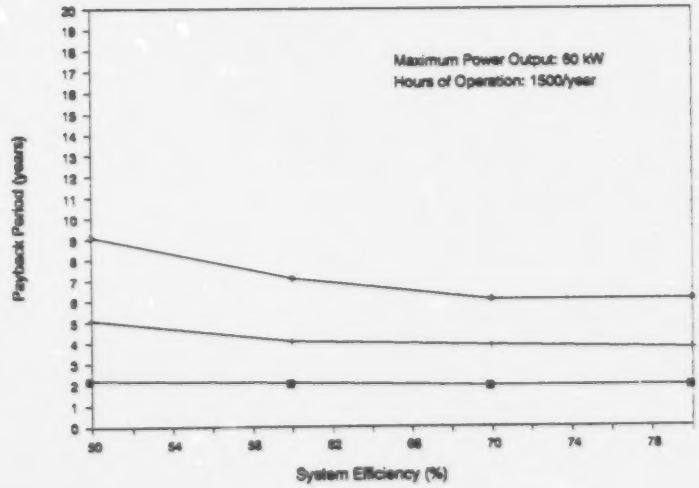
Graph 11a

Initial System Cost:

- $ 15000
- $ 10000
- $ 5000



Graph 11b



Graph 11c

7.0 CONCLUSIONS

1. Most stokers and pre-heaters tested gave good handling and combustion results with screened chips and pelletized fuels. Some pre-heaters could handle all non-compact fuels: screened and unscreened chips, pellets, peat chunks.

Particulate fuel burners have been found capable of very low particulate emissions. Their levels were often below the maximum permissible 1988 level of 8.5 g/h imposed on woodstoves by the EPA in the United States.

2. No appliance gave good combustion results with fuels such as sawdust, chipper fines, and whole tree chips where the fine material fills the interstices among the larger pieces of material, and thus prevents proper mixing with oxygen, i.e. it prevents turbulence.

3. Fuel delivery unreliability is one of the major problems with particulate fuel burners.

While stokers and pre-heaters are very efficient burners of biomass fuel and offer several advantages over their furnace and woodstove counterparts, their feed systems are still incapable of guaranteed delivery of chips to the combustion zone. We experienced occasional jamming of particulate fuel in the augers, and bridging of fuel in the surge bins.

4. It is difficult to design a particulate fuel burner that will handle the many variations in size and moisture content of particulate fuels.

Incompatibility between the fuel and the feed mechanism causes many problems. Pelletized fuels, because of their size and uniformity, are ideally suited to particulate fuel burners. They cause little or no feed problems. They can be handled by much smaller motors and augers. For the same energy output, pelletized fuels can be as economical as hardwood chips.

5. Arbitrary choice of a furnace or boiler for coupling to a stoker or pre-heater can create a mismatch, robbing the system of efficiency and increasing its emissions.

This can transform a good stoker into an uneconomical appliance. Testing has shown that many existing wood furnaces and boilers are not ideal choices for use as heat exchangers with particulate fuel burning appliances.

6. Most burners tested presented no high-fire problems for their own components or for those of the attached heat exchanger.

However, the use of drier fuels or more energy-dense fuels, could result in the development of higher temperatures.

On two burners, control circuits were positioned too close to the combustion area.

7. All combustors had potential burnback problems.

8.0 RECOMMENDATIONS

1. Restrictions should be placed on the installation of particulate fuel burners to ensure that they can be used safely and efficiently. Stokers and pre-heaters should be certified only as stoker systems and pre-heater systems to the CSA B366.1 standard. Manufacturers may recommend their stokers or pre-heaters for coupling to as many heat exchangers as they wish, as long as each individual combination has been certified. This will prevent dangerous mismatches.

2. R & D should be done on the design of "universal" heat exchangers able to accommodate stokers and pre-heaters in output ranges from 25 to 75 kW. These could be used as retrofit heat exchangers for most particulate fuel burners.

3. In those areas where pelletized wood fuels are available at competitive prices, we recommend their use in particulate fuel burners. The latter includes unit pellet furnaces of the type described in Appendix E.

4. Maximum emissions limits for various types of appliance should be included in the CSA B415 standard and either Environment Canada or the provinces should legislate maximum emission levels for solid-fuel-burning appliances, based on CSA B415. Also, we recommend that the B415 limit for stoves be identical to the EPA limit.

5. Strong efforts should be made to promote the manufacture of chip-fired appliances, similar to the Swebo (in a range of sizes) and the TP30 kW, in Canada. The biggest obstacle to sales of such systems is the lack of efficient chip-handling technology and lack of knowledge of the associated costs.

6. We recommend that high priority be given to the development and testing of a combustion appliance for softwood sawdust.

APPENDIX A

DESCRIPTION OF APPLIANCES USED IN TEST PROGRAM

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a) TP2000 30 kW STOKER (Fig. 2)

The TP2000 30 kW stoker is built in Finland. The manufacturer's advertising brochure may be found in Appendix F. The stoker consists of a surge bin, an auger feed mechanism, and a cast steel combustor tube.

The rectangular surge bin has a volume of 0.43 cubic metres (16.5 cu ft). The bin cover is gasketed. Lying horizontally in the bottom of the bin, there is a large iron wheel with an attached wire whip. The wheel has teeth which are intermeshed with the flights of the auger. When the auger operates, it turns the wheel. Both the wheel and whip's rotation act as agitators and are intended to disturb fuel and prevent bridging in the bin.

The auger is positioned in the bottom of the bin and is driven by a 110-volt fixed-speed electrical motor. The auger's rotational speed is controlled by varying the radial distance between an ox-yoke attachment on the auger shaft and a ratchet mechanism. The auger's rotational speed controls feed rate.

The 10 mm (4-inch) auger pushes fuel through a 12 mm (4-3/4 inch) diameter tube to a cylindrical cast steel combustor tube. A fan supplies combustion air through a series of small holes in the tube, and combustion takes place within this tube.

The stoker's heat output is controlled by a thermostat. It regulates both the combustion air fan and the auger feed. When there is no call for heat, the stoker maintains its fire by operating on a "hold-fire" mode. In this mode both the combustion air fan and the auger feed are operated on a periodic basis to keep burning fuel in the combustion chamber. This "hold-fire" sequence may be adjusted to burn from a minimum of 5 seconds every 6 minutes, to a maximum of 30 seconds every 2 minutes. This will vary depending on the fuel type and moisture content.

b) TP2000 50 kW STOKER

The TP2000 50 kW stoker is built in Finland. The manufacturer's advertising brochure may be found in Appendix F. The larger TP2000 stoker is manufactured with the same basic characteristics as the smaller model with the exception that it has an open combustor bowl instead of a closed tube. The stoker has an auger feed mechanism with fuel agitator, a surge bin and electrical controls to regulate the hold-fire sequences and interface with the thermostat.

The surge bin is built up from several panels which are bolted together. The bin's size can be increased to 2 cubic metres (70 cu ft). The bin is sealed and its cover is gasketed.

In the bottom of the bin a 9 mm (3-1/2 inch) auger is used to move particulate fuel. The auger is powered by a 1/2 hp motor and adjusted to different speeds by a ratchet mechanism. The auger's flights are intermeshed with those of a large iron wheel which rotates in the bottom of the bin. A wire whip is attached to the large iron wheel and their rotation agitates the fuel to help prevent bridging.

The auger delivers fuel through a 11.5 mm (4-1/2 inch) diameter tube to a rectangular cast iron combustor bowl. Unlike the smaller 30 kW model, the combustor bowl is open at the top. A fan supplies combustion air through a series of small holes in the sides and through three moveable grates on which combustion takes place. The grates move back and forth to prevent ash buildup.

The TP2000 50 kW was originally wired for 3-phase 220-volt current but because 3-phase service is not available, the wiring was converted to single phase by a phase shifter. We were not satisfied with this setup and the distributor replaced the original electrical system with a 110-volt, single-phase system.

The stoker's operation is controlled by a thermostat. When there is no heat demand, the stoker switches over to its "hold-fire" mode where both the feed mechanism and the combustion-air fan operate on a periodic basis to keep the fuel lit.

The TP50 is less efficient than the TP30. When the latter was up-sized, the heat developed in the combustor tube was greater than the material could withstand, hence the change in design.

c) VALLSTA 40 kW STOKER (Fig. 5)

The Vallsta stoker is built in Sweden. Particulate fuel is fed from the surge bin by a screw auger to the combustion zone, which consists of an overfed steel combustor bowl. An electronic control unit monitors the combustion process. A douser system protects against burnback of fuel.

The surge bin is circular and measures only 30 cm (12 inches) in height (in order to minimize shipping costs). We ordered an extended bin from the distributor. This enlarged bin was 120 cm (48 inches) high and had a volume of 0.63 cubic metre (22.5 cu ft).

Particulate fuel is brought to the combustor bowl by a screw auger powered by a gear motor. The auger's teeth intermesh with those of a large iron wheel which rotates at the bottom of the surge bin. The function of the wheel is to agitate the fuel and to prevent it from bridging. Fuel is ignited automatically by an electrical resistance coil located in the combustor bowl. Combustion air is supplied into the combustion bowl by a fixed-speed fan with an adjustable opening.

The Vallsta operates on a 220-volt, single-phase power supply. The motor is thermally protected. This is essential in case of jamming. A micro-processor controls the ignition process and the fuel feed rate. A photocell monitors the presence of flame and stops fuel feed should the fire become extinguished. The electrical system is almost identical to that of the Iwabo.

A mechanical, thermally-activated douser system provides protection against burnback of fuel in the auger tube.

d) SWEBO 65 kW PRE-HEATER (Fig. 7)

The Swebo is a Swedish-built pre-heater. It is equipped with a combustion chamber, a surge bin, a screw auger, an agitator mechanism and a control unit.

The appliance is rated at 65,000 kilocalories which is equivalent to 76 kW. It can operate at a steady output of 90 kW, using green hardwood chips.

The surge bin is rectangular at the top and tapers to a circular shape at the bottom. It has a volume of 0.71 cubic metre (25 cu ft). To prevent bridging of fuel, a horizontal shaft fitted with a large vertical wheel and 2 semi-circular steel arms rotates inside the bin. The agitator is driven by the auger whose flights intermesh with teeth on the vertical wheel.

A 110-volt electrical system powers a 1/2 hp gear motor which drives the auger shaft. A 85 mm (3-3/8 inch) diameter auger rotates inside 125 mm (5 inch) square tubing.

The Swebo's electrical control regulates fuel feed rates, combustion fan speed and hold-fire modes. Fuel feed rates are chosen from a 0 to 100% adjustment of the auger motor's operating time over a 50-second operating cycle. Combustion air is regulated by a variable speed fan. This air is introduced as a combination of underfire and overfire air. The hold-fire mode can be adjusted from 0 to 10% of the motor's operating time.

The cylindrical combustion chamber is lined with a thick layer of refractory material. Inside the combustion chamber a paddle, connected to an outside switch, stops fuel feed should the combustion chamber become overfilled with fuel. The Swebo unit which we tested was not equipped with a douser system.

The Swebo can be fitted with a Nymo combustion head and control system, which incorporates automatic ignition. This combustion head is reputed to be better than the Swebo head for dry fuel.

The Swebo is manufactured in 5 sizes rated approximately as 76, 151, 185, 232 and 290 kW respectively.

e) IWABOMATIC X-5 PRE-HEATER 40 kW (Fig. 6)

The Iwabo pre-heater is built in Sweden. It consists of a combustion chamber where the particulate fuel is burnt, a screw auger which delivers fuel to the combustion chamber, a micro-processor unit which regulates ignition, feed rate and the combustion process, a douser to extinguish any burnback and a surge bin.

The Iwabo was delivered with one set of side panels which increased the bin's capacity to 0.56 cubic metres (19.7 cu ft). The bin's sloped portion is similar to a moving floor: four scrapers move to-and-fro about 10 cm (4 inches) along the base of the floor to loosen material and prevent bridging.

Particulate fuel is brought to the combustor bowl by a screw auger powered by a gear motor. The auger's teeth intermesh with those of a large iron wheel which turns at the bottom of the surge bin. The purpose of the wheel is to agitate the fuel and to prevent it from bridging. Fuel is ignited automatically by an electrical resistance coil located in the combustion chamber. Combustion air is supplied into the combustion chamber by a fixed-speed fan with an adjustable opening. The electrical system is almost identical to that of the Vallsta.

The Iwabo is equipped with two safety devices. A safety switch on the combustion chamber stops the feed if the combustion chamber becomes separated from the feed tube and bin. This prevents fuel from being fed after a combustion chamber full of fuel has been forced away from the auger tube and surge bin. The Iwabo is also fitted with a douser system to prevent burnback. Obviously the douser will not extinguish a burnback if it is not filled with water either because of neglect or because it has been previously activated.

f) DAN TRIM MINIMATIC PRE-HEATER

The Dan Trim pre-heater is shipped as two separate components, a combustion chamber and a surge bin.

The surge bin has a volume of 0.16 cubic metres (6 cu ft). The bin is small and was not manufactured with provision for enlargement. Its small size is impractical for use with low energy fuels such as sawdust or shavings. The surge bin has an agitating mechanism to prevent fuel bridging. Springs are attached to two shafts which rotate to-and-fro in a 180 degree motion. The bin's cover has a safety switch which prevents operation of the unit should the cover be left open or unlatched.

The auger motor and control panel are housed beneath the surge bin. In the second unit, which houses the combustion chamber, we also find the combustion air fan, the ash removal auger and pan, a douser system and a water recirculation system to cool the combustion chamber.

The Dan Trim we received operates on a 110-volt power source. Its control panel has an adjustment for light or heavy fuel types and two adjustments to regulate feed rate. The "on-time" adjustment regulates the length of time the auger runs and the "pause-time" adjustment regulates the time between successive "on-time" cycles. In addition there is an adjustment for the Dan Trim's hold-fire mode. The control panel is equipped with useful trouble lights which indicate the location of operational problems.

The auger screw delivers fuel from the surge bin into a refractory-lined combustion chamber. Ignition was supposed to be provided automatically by heat gun (an electrical coil through which air is blown). This heat gun igniter could not even light paper. The combustion air supply has two adjustments, one for primary air and one for secondary air. The combustion chamber is cooled by water circulation. Because of this plumbing requirement, the Dan Trim is probably best suited for coupling to a boiler.

The Dan Trim is equipped with several safety devices. A photocell monitors the flame in the combustion chamber and stops both the feed and combustion air should the fire become extinguished. A heat sensor in the ash removal area stops the feed and combustion air if high temperatures are registered. This prevents a fire from being fuelled in the ash removal tray.

The electrical system on this appliance gave us considerable difficulties (see p. 42).

g) TILLEY 175,0000 Btu/h UNIT APPLIANCE

The Tilley burner is made in New Brunswick. It is made up of three sections: the surge bin, the combustion chamber and the heat exchanger. It is one of the few particulate fuel burners manufactured in Canada and is ULC listed.

The surge bin is rectangular and tapered from top to bottom. Its capacity is 0.7 cubic metres (27.5 cu ft). It is equipped with an oscillating horizontal shaft with vertically-protruding steel pins that stir the fuel and prevent it from bridging. The shaft is operated by an ox-yoke mechanism.

A 114 mm (4-1/2 inch) auger positioned in the bottom of the bin feeds fuel through a 203 mm (8 inch) square tunnel. The auger is chain driven by a gear motor. The Tilley is a batch feeder. The auger drops fuel into the combustion chamber and creates a fuel break. This break provides burnback protection. A high-level switch stops fuel supply when the fuel reaches a certain level in the combustion chamber. A control panel regulates the operation of the appliance and a douser adds to burnback protection.

The combustion chamber is made of steel and is air-cooled to prevent it from overheating. This cooling of the combustion chamber makes poor sense for combustion efficiency. Combustion air is regulated by a motor-operated damper and is supplied by natural draft only; this limits the stoker's heat output. Solenoids activate oscillating grates that act as a de-ashing mechanism. Both the solenoids and the ox-yoke contribute to a very noisy appliance.

The stoker feed mechanism operates on a cycle: a photocell monitors the flame and feeds additional fuel as soon as the fuel is low enough to expose the hot coals.

APPENDIX B

ASSUMPTIONS FOR COST-BENEFIT ANALYSES

APPENDIX B

ASSUMPTIONS FOR COST-BENEFIT ANALYSES

The following assumptions were made in the selection of the variables for Graphs 10a, 10b, 10c, 11a, 11b and 11c.

In 10b and 10c the "maximum power output of system" is assumed as 60 kW continuous for 8 hours of operation per day, 7 days per week, over 6 months. This amounts to a total of 90000 kW/h for 1500 hours annually. These power requirements would correspond to the needs of a small commercial operation or a large house.

When the "hours of operation per year" were varied they ranged from 750 to 3000 (Graph 10b). The 750 represents 3 hours per day for 3 months while the 3000 represents 12 hours of operation per day for 6 months.

The following variables remained fixed for the cost-benefit analyses:

Oil cost: at 32.9¢ per litre for Graph 10 and 42.9¢ per litre for Graph 11.

Energy output from oil: 38.4 MJ/litre (26.9 MJ/litre based on 70% efficiency)

Cost of hardwood chips: $\$19.17/m^3$

Energy output from hardwood chips: 4800.6 MJ/m^3. This is the heat content of the chips we used. Output varies according to chip species, size etc.

The estimated maintenance cost associated with each of the installations was set at 5% of installation cost. Therefore, a $10000 installation would cost $500 in maintenance per year. Costs associated with maintenance would include cost of parts, small repairs and an annual overhaul. It would not include time for filling surge bins and for ash removal.

Amortization rate: 12.5% per annum.

APPENDIX C

SIEVE ANALYSES

TESTING & INSPECTION GEOTECHNICAL SPECIALISTS
CONCRETE • ASPHALT • STEEL • SOILS • PILING • ROOFING

FONDEX
CONSULTING ENGINEERS

le 26 janvier 1988
Dossier: 0-8832

IRTA
R.R. No. 1, B.P. 205,
Clarence Creek, Ontario.
K0A 1N0

Compétence de M. Charles Lemay

OBJET: Granulométries sur les matériaux de copeaux de bois et de bran de scie

Monsieur,

Nous vous transmettons par la présente les résultats des essais provenant des échantillons reçus au laboratoire le 12 janvier 1988.

Nous espérons le tout conforme. Si vous désirez de plus amples détails à ce sujet, n'hésitez pas à communiquer avec notre bureau.

Bien à vous,
FONDEX LIMITED

Roland D. Drouin, P.Eng.
préparé par J.-C. Surprenant, Tech.

JCS/am
p.j.

ESSAIS & INSPECTION • SOLS • PIEUX • BÉTON • ACIER & ASPHALTES

FONDEX LTÉE
HULL MONT-LAURIER

GRANULOMÉTRIE

CLIENT: IRTA - Clarence Creek

PROJET:

PROVENANCE DU MATÉRIAU: I. M. R.

DATE ÉCHANTILLONNÉ: 12 Janvier 1988 PAR: Client

DATE LIVRE: 12 Janvier 1988 PAR: Client

NO. DU LABORATOIRE: 1525 DATE D'ESSAI: 15 Jan. 1988

MATÉRIAU EMPLOYÉ: Copeaux de bois

DEVIS:

POIDS DE L'ÉCHANTILLON:

TAMIS NO.	POS. RETENU	% RETENU	% RETENU CUMULATIF	% PASSANT	LIMITES DU DEVIS-% PASSANT
25 mm				100	
22.4				99.4	
19				94.9	
16				78.6	
12.5				63.0	
9.5				31.5	
4.75				6.2	

MODULES DE FINESSE:

REMARQUES:

ESSAI PAR: T.M. DATE: 15 Jan. 1988

VÉRIFIÉ PAR: JCB DATE: 15 Jan. 1988

COPIES:

ESSAIS & INSPECTION • SOLS • PIEUX • BÉTON • ACIER & ASPHALTES

FONDEX LTÉE
HULL MONT-LAURIER

GRANULOMÉTRIE

CLIENT: IRTA - Clarence Creek

PROJET:

PROVENANCE DU MATÉRIAU: Clarence Creek

DATE ÉCHANTILLONNÉ: 12 Janvier 1988 PAR: Client

DATE LIVRE: 12 Janvier 1988 PAR: Client

NO. DU LABORATOIRE: 1526 DATE D'ESSAI: 14 Jan. 1988

MATÉRIAU EMPLOYÉ: Brin de Scie

DEVIS:

POIDS DE L'ÉCHANTILLON:

TAMIS NO.	POS. RETENU	% RETENU	% RETENU CUMULATIF	% PASSANT	LIMITES DU DEVIS-% PASSANT
22.4mm				100	
19				99.8	
16				99.7	
12.5				99.3	
9.5				98.8	
4.75				70.5	

MODULES DE FINESSE:

REMARQUES:

ESSAI PAR: TM DATE: 15 Jan. 1988

VÉRIFIÉ PAR: [illegible] DATE: 15 Jan. 1988

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FONDEX LTÉE
HULL MONT-LAURIER

GRANULOMÉTRIE

CLIENT: IRTA - Clarence Creek

PROJET:

PROVENANCE DU MATÉRIAU: Claude Brunet

DATE ÉCHANTILLONNÉ: 12 Janvier 1988 PAR: Client

DATE LIVRE: 12 Janvier 1988 PAR: Client

NO. DU LABORATOIRE: 1524 DATE D'ESSAI: 15 Jan. 1988

MATÉRIAU EMPLOYÉ: Copeaux de bois

DEVIS:

POIDS DE L'ÉCHANTILLON:

TAMIS NO.	POS. RETENU	% RETENU	% RETENU CUMULATIF	% PASSANT	LIMITES DU DEVIS-% PASSANT
37.5 mm				100	
25				97.9	
22.4				95.5	
19				91.1	
16				81.9	
12.5				74.0	
9.5				37.3	
4.75				5.5	

MODULES DE FINESSE:

REMARQUES:

ESSAI PAR: T.M. DATE: 15 Jan. 1988

VÉRIFIÉ PAR: SB DATE: 15 Jan. 1988

COPIES:

APPENDIX D

ADDITIONAL FUEL TYPES

APPENDIX D

ADDITIONAL FUEL TYPES

i) Green softwood chips

The green softwood chips were purchased from a logging company. The chips were unscreened and some pieces were fairly large. We were told by the company that the larger pieces were produced when the knives hit tree knots. The moisture content of these chips was 50%.

ii) Green whole-tree chips - softwood

We had originally placed an order for whole-tree chips, both softwood and hardwood, from the logging company. There was some confusion with the owner as to why we required the whole-tree chips and they were made without tree tops or branches. Faced with this predicament we decided to make up "whole-tree" chips from a mixture of softwood chips and tree-top chips obtained from a nearby coniferous plantation. The tree-top chipping operation produced mostly fines which had been left to rot. We gathered a supply of these fines and mixed them in a 1:4 ratio, by weight, with the chips. The moisture content of these green "whole-tree" chips was 55%.

The logging company that supplied the softwood chips explained that they did little or no whole-tree chipping because it was uneconomical. Their large chipper was parked at one central location. De-branched logs were dragged to this location and chipped directly into 45-foot trucks. It would not be possible to have the large chipper brought to all the cutting areas. A smaller chipper would be uneconomical because its capacity would be too small for a large scale operation.

iii) Chips from stockpiled slabs

Stockpiled slabs were picked up from a forest product company and were chipped by the logging company. Chips were unscreened and had fairly large pieces. After burning some of these chips we were surprised to discover an unusually large quantity of sand and stones in the ash. The stones measured from one to five centimetres in diameter. This gravel probably originated from the bagging of chips that were piled on sandy soil. The moisture content of these chips was 40%.

iv) Ground bark

Ground bark was obtained from a company in Lanark, Ontario which debarks sawlogs. The ground bark was bagged from a stockpile which was outdoors. Its moisture content was 56%. The fuel was too wet to burn and required drying to 45%.

v) Fines from screened chips

The fines from screened chips were obtained from a lumber company in Lanark, Ontario. This material is the finer pieces which are removed when screening chips. They measure 8 mm and smaller in diameter (5/16 inch). They were stockpiled outside and had a moisture content of 55%. In this form the fines were too wet to burn and the fuel was dried to 40%.

vi) Peat

Peat was obtained from Avalon Peat Harvesting in St. Shott's, Newfoundland. The peat had been compressed into cylindrical chunks approximately 5 centimetres in diameter, 10 to 25 centimetres in length. In order to use the fuel as particulate fuel in the stokers, the fuel was chopped into pieces of two to four centimetres in length. There was a large proportion of fine dust in the fuel. The peat's moisture content varied from 25 to 65%.

vii) Wood waste fuel pellets

Wood waste fuel pellets were manufactured by N. S. Bauman Ltd, in Wallenstein, Ontario. The company also pelletizes animal feed. We purchased the pellets from a distributor in Lanark, Ontario. Moisture content of the pellets was 8%.

APPENDIX E

SUMMARY OF TESTS DONE ON THE RENFYRE PELLET FURNACE

APPENDIX E

SUMMARY OF TESTS DONE ON THE RENFYRE PELLET FURNACE

Under another contract IRTA conducted performance tests on a Renfyre pellet furnace. The furnace is a unit appliance made by Maco Enterprises in Drayton, Ontario. It is made up of two parts: a storage component which includes the pellet storage bin, feed mechanism and combustion air fan, and a second part which includes the combustion chamber, heat exchanger and circulation fan. More information on the appliance may be found in the manufacturer's brochure in Appendix F.

The furnace's heat output with wood pellets, for continuous operation, was approximately 90 MJ/h (85,000 Btu/h or 25 kW). The maximum emission levels were lower than the maximum 1988 EPA limit of 8.5 kg/h for woodstoves, even when the pellet furnace was operating at full output. When operated with peat pellets, emissions were still lower.

The efficiency level of the Renfyre was slightly above 70% for burn rates from 2 to 7 kg/h. Although this efficiency could be slightly increased by adding heat exchange area, it compares well with stoker-system efficiencies (ref. Graph 1).

The Renfyre pellet furnace demonstrated that it is a viable alternative to stokers or pre-heaters for those areas where pellet fuel is available. The Renfyre pellet furnace operated quietly and with very few feed problems. The model we tested was well engineered and sold for half the price of its European counterparts.

RENFYRE
Renewable Energy Fueled Heating Equipment

MACO ENTERPRISES

R.R. 2
Drayton, Ontario N0G 1P0
Telephone (519) 638-2746

The All New Furnace . . .

The all new furnace for burning wood pellets.

Now you can have the comfort of "wood" heat with practically the same convenience as from other fuels.

Heavy 10 gauge primary heat exchanger and 14 gauge secondary heat exchanger. Cast iron retort for long life.

Fuel is fed from a built-in hopper through a feed-screw to the retort inside the primary heat exchanger, where forced draft is added for complete combustion. The exhaust gases must pass through a built-in baffle system before entering the secondary heat exchanger tubes and then finally to the stack.

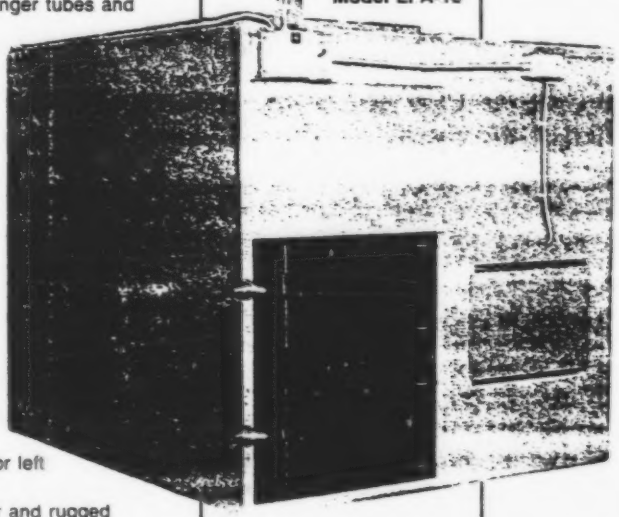
An electrically operated control is provided for maintaining a minimum fire when the thermostat is not calling for heat. Under normal conditions, the fire maintains itself after the first initial light-up. If for any reason, the fire would go out, the unit will automatically shut down to prevent unburned fuel from being fed into the unit.

The use of wood pellets, compared to firewood, is much safer. The moisture content is considerably lower than air-dried firewood, therefore maintaining a hotter and more intense fire. With the higher temperature fire, more gases are completely burned with virtually no smoke or creosote.

It is designed for . . .
- total home comfort
- ease of maintenance
- high efficiency

Safety features such as:
- thermostatically controlled
- over fire controlled
- out fire controlled

Model LFA-18



- Stoker can be mounted on either right or left hand side of furnace.
- One motor drives fan for combustion air and rugged gear reducer to feed fuel to the fire.
- Flue collar 6"
- Approved to Canadian & U.S. requirements

Approximate Casing Dimensions
49 inches wide with stoker
56 inches long
46 inches high

Plenum dimensions
Warm air 26¼" x 22¼"
Return air 20" x 22¼"

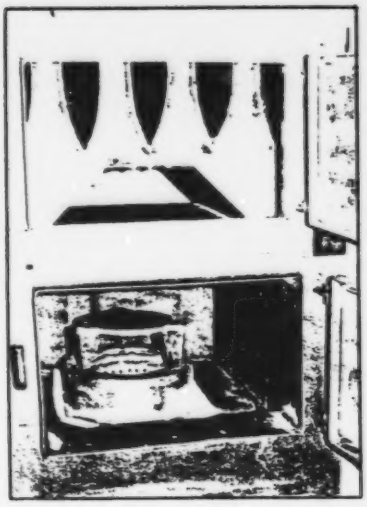
Maximum input 18 lbs. per hour
Pellets rated at 8,000 BTU per lb.

A unique ash removal system is built into unit to minimize dust outside furnace.

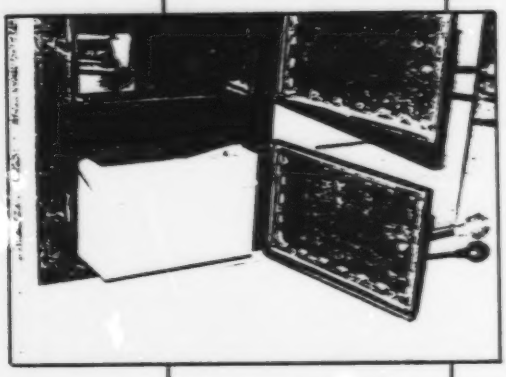
Furnace is designed with the consumer in mind.

Ease in flue cleanout.

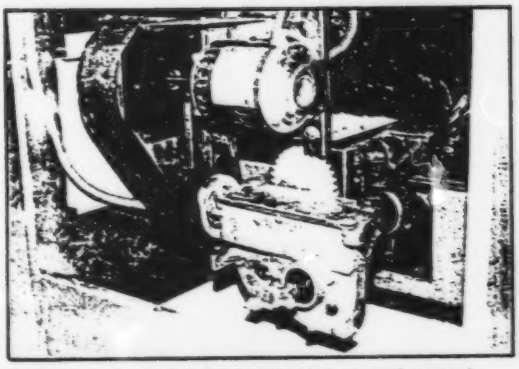
Burner Plate above fire for more complete and efficient burning.



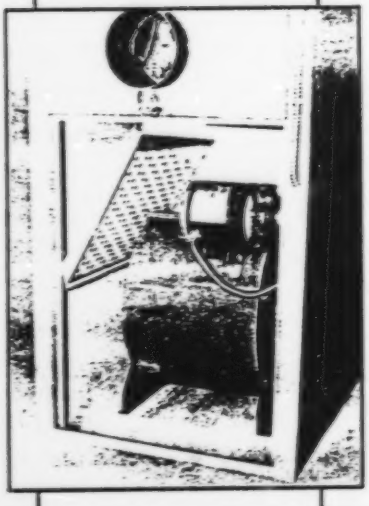
Ease in flue cleanout. Cast iron retort for long life. Burner plate above fire for more complete & efficient burning.



A unique ash removal system is built into unit to minimize dust outside furnace.



One motor drives fan for combustion air and rugged gear reducer to feed fuel to the fire.



Large capacity blower to circulate heat throughout the home.

LFA-18 Wood Pellet Furnace

SAVE THESE INSTRUCTIONS

Minimum installation clearance and physical dimensions

Fire door end - 48"

One side - 24"

Stoker side - 24"

Side wall to pipe - 32"

Floor - noncombustible

Flue pipe - 18"

Plenum top - 4"

Back wall - 30"

Flue pipe connection - 24 gauge blued steel

Approximate Casing Dimensions

49" wide with stoker

56" long

46" high

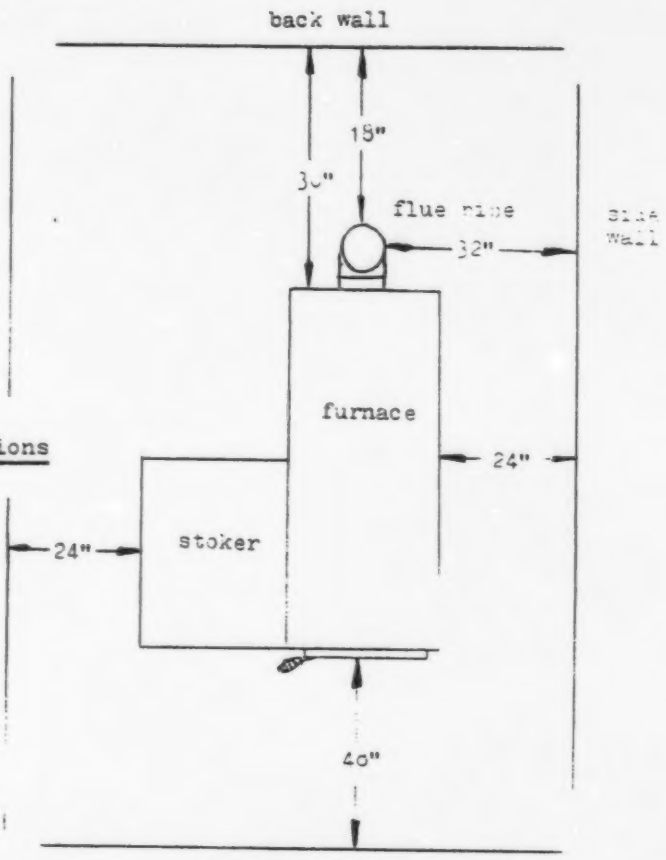
Plenum Dimensions

Warm air - 26¼" X 22½"

Return air - 20" X 22¼"

Flue collar - 6"

Filter size - 16" X 20"



INSTALLATION CLEARANCES
(top view)

MACO ENTERPRISES
R.R. 2
Drayton, Ontario N0G 1P0
Telephone (519) 638-2746

APPENDIX F

APPLIANCE INFORMATION FROM MANUFACTURERS

Tehokasta tekniikkaa pannuhuoneeseen

TP 2000 poltin

- Laita TP 2000 poltin kattilaasi — kotimaisen polttoaineen helpoin käyttötapa.
- Ei savuhaittoja.
- Polttoaineena hienohake, palaturvemurske tai pelletti.
- Poltin on automaattinen ja varmatoiminen.
- Erittäin korkea hyötysuhde takaa vähäisen polttoaineen kulutuksen.

Kolme kokoa:
- 180/10 kW
- 360/17 kW
- 500/25 kW

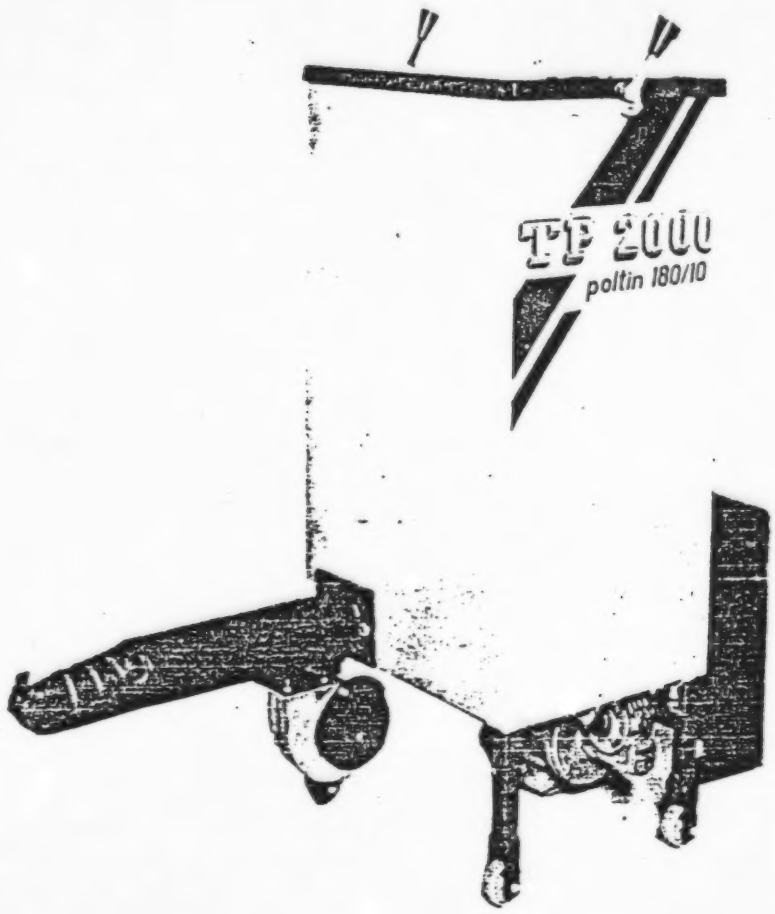
- Poltin voidaan asentaa useimpiin eri kattilatyyppeihin.

MYYJÄ:

Tmi
Topi Pämppi
27100 EURAJOKI
☎ 938-80 222

TP 2000 STOKER

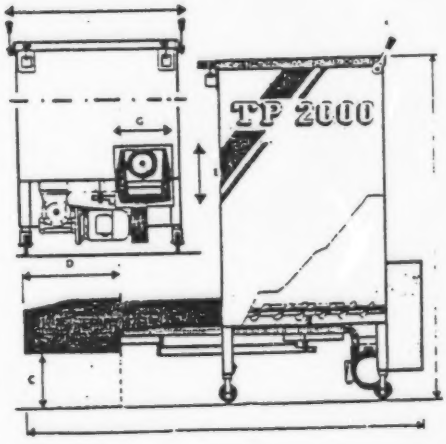
FOR
BIOFUEL COMBUSTION



FOR WOODCHIPS AND VARIOUS FUEL PELLETS.
Capacities: 30 000, 60 000, 90 000 & 150 000 BTU

TP 2000 STOKER

Measurements
(in inches)



	Capacities x 1000 BTU			
	30	60	90	150
A	43	57	61	79
B Min	45	51	51	59
B Max	49	51	51	---
C Min	13	12	12	20
C Max	17	13	13	20
D	12	14	15	16
E	Ø5	Ø7	10	12
G	Ø5	Ø7	10	12
F	20	24	28	40
Volume of reservoir (gal)	47 g	94 g	130 g	260 g
Weight lbs	240	280	400	660

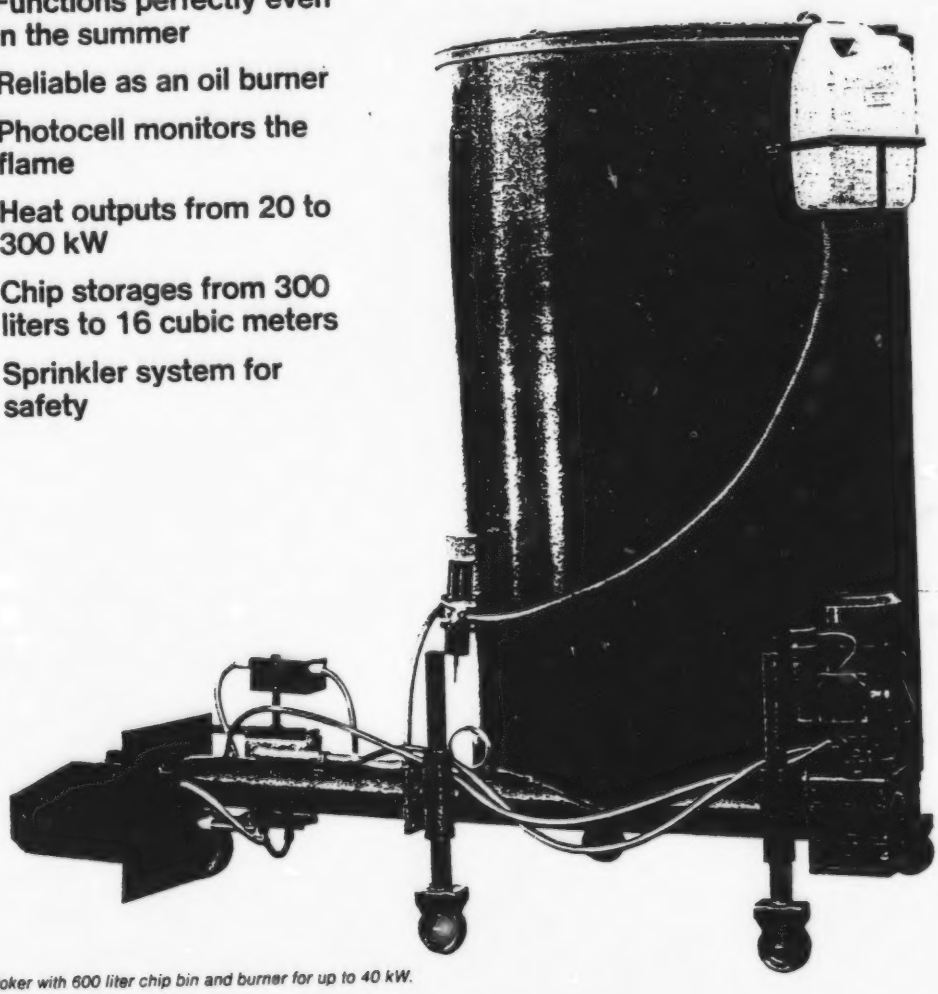
The function of the stoker is regulated by the control panel which is connected to the boiler thermostat of a hot-water boiler or a room thermostat in a hot-air furnace system. The stoker burner operates only when heat is required. The fuel is kept smoldering by the control unit when heat is not required.

The combustion bowl is cast iron. A fixed grate is used in the two smallest units, otherwise a mechanical grate is employed.

THE VALLSTA STOKER

Electronically controlled chip burner with electrical ignition.
Ignites and shuts off automatically.

- Functions perfectly even in the summer
- Reliable as an oil burner
- Photocell monitors the flame
- Heat outputs from 20 to 300 kW
- Chip storages from 300 liters to 16 cubic meters
- Sprinkler system for safety



Stoker with 600 liter chip bin and burner for up to 40 kW.

VALLSTA MEKANISKA

The Vallsta Stoker

Chip heating with oil burning features

A fully automatic chip burner that ignites and shuts off the flame just like an oil burner. The burning is controlled by the furnace thermostat.
The unit is very reliable and needs almost no monitoring.

The Vallsta Stoker is a system of modules including chip burner, chip screws and chip storage for heat outputs from 20 to 300 kW.

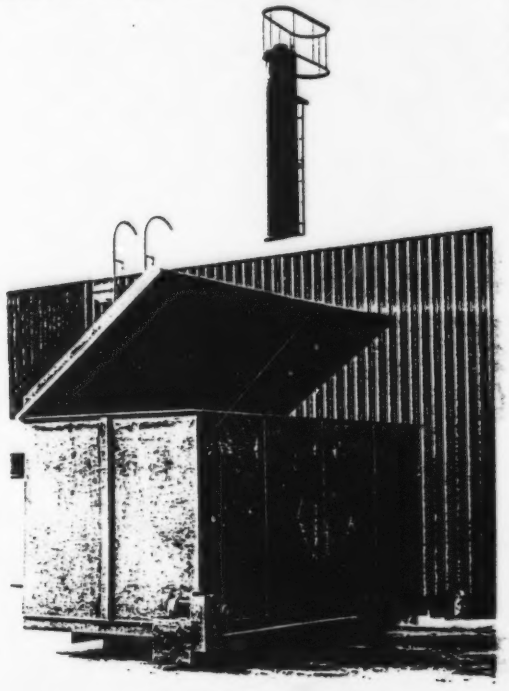
The Vallsta Stoker can be combined with most furnaces on the market.

The Vallsta Stoker is also available as a complete furnace room with chip storage and furnace in a container design – easy to move, easy to connect to a heating system.

Function

The Vallsta Stoker functions basically like an oil burner controlled by the furnace thermostat. When the thermostat is activated, a glow spiral is heated up, and chips are fed in for approx. 50 seconds. The air fan starts working and warm air passes over the glow spiral, thus igniting the chips. A photocell notices the flame and gives an impulse which starts the stoker screw again. The glow spiral is shut off, and the stoker is in operation.
When the furnace has reached its maximum temperature setting, the furnace thermostat is de-activated. The stoker screw stops while the fan works a few more minutes to make sure that all of the chips burn up. As a safety against so-called backfire, the stoker screw feeds in more chips for a few seconds.
The cycle starts again when the furnace thermostat is re-activated at its minimum temperature setting.
The photocell monitors the flame constantly and shuts off the stoker screw when too much fuel is fed in or if the chips are too wet to burn properly.

16 cu.m chip storage with variable-speed feeder screw.



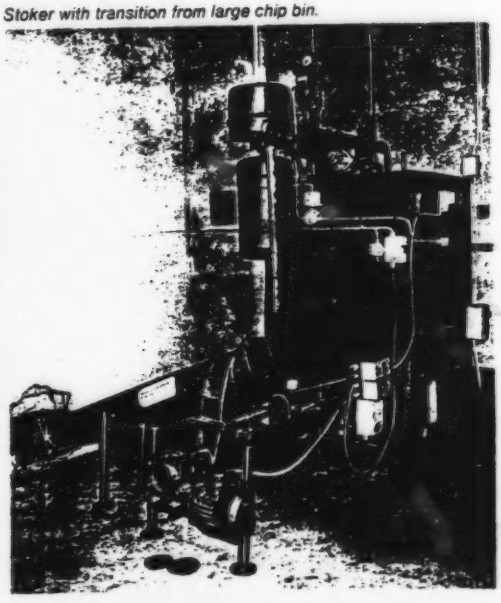
Choice of size

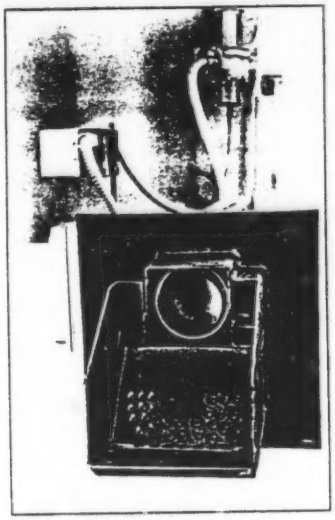
The size of the stoker unit depends on the size of the furnace, the heating need and local chip storage facilities.
For one-family houses and other projects where heating requirements are low, chip bin, stoker and chip burner are usually delivered in one unit. For larger heating needs and when it is possible to store larger quantities of chips, a larger chip bin of up to 16 cu.m combined with one or more screws and suitable transitions will be offered.

Installation

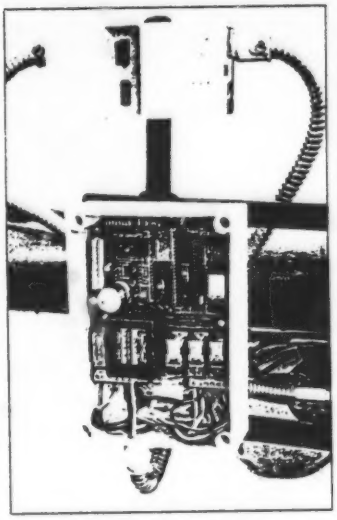
The stoker can be connected to most existing furnaces by removing a hatch and adjusting the stoker in height to fit the opening, if required. The stoker can also be installed on the side of the furnace.
Electrical connections should be made by a licensed electrician.

Stoker with transition from large chip bin.

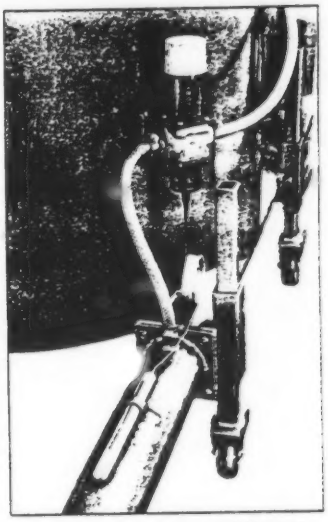




Chip burner with cover towards the furnace opening.



Micro-processor which controls combustion.



Sprinkler system, sensor and thermal valve.

Design

The Vallsta Stoker is composed of chip bin, stoker, chip burner and equipment for control and monitoring of the combustion process.

Chip bin. The smallest stoker has a 300 or 600 liter chip bin as standard. Larger stokers have chip bins from 2 to 16 cu.m. But even the smallest stoker can be equipped with a larger chip bin.

Stoker screw. The chips are fed to the burning bowl by a screw conveyor which is driven by a gear reduction motor. The stoker screw drives an agitator in the chip bin so that all chips can be fed out. For longer transport distances, several screws are used. Each transition is equipped with level control and inspection hatch.

Chip burner. The burner consists of a chip bowl with ignition spiral and air fan. The ignition spiral ignites the chips at the start of each cycle.

Electronics. A micro-processor is the brain of the electrical system. It controls ignition and shut-off as well as the stoker screw and monitors the combustion process by means of a photocell. The micro-processor gives extreme safety when heating with chips.

Sprinklers. A sensor on the stoker screw feels the temperature in the stoker and activates a valve, thus letting water into the stoker if "backfire" occurs.

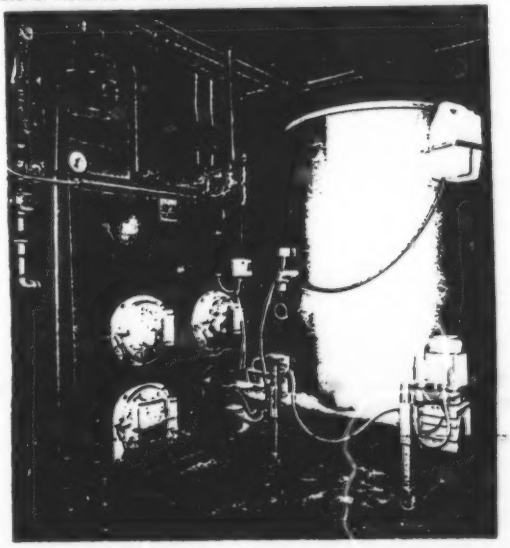
Accessories

Burner for pellets.

Automatic ash removal (for larger units only).

Variable drive for the stoker screw to adapt feeding speeds to different chip qualities.

Stoker installed in front of the furnace.



Heating plants

For larger heating requirements, we can offer complete plants with chip storage, furnace room, furnace and chimney, built as a unit in a container.
This unit can be put anywhere and be connected to the heating system through a culvert, which is often more favourable than combining the chip bin, feeding screws and burner with an old furnace.

Drying

The automatic system of the Vallsta Stoker makes it ideal as a source of energy for hot-air processes, kiln driers, grain driers and the like.

Complete heating unit delivered to an estate and connected to the heating system through a culvert.

Technical data

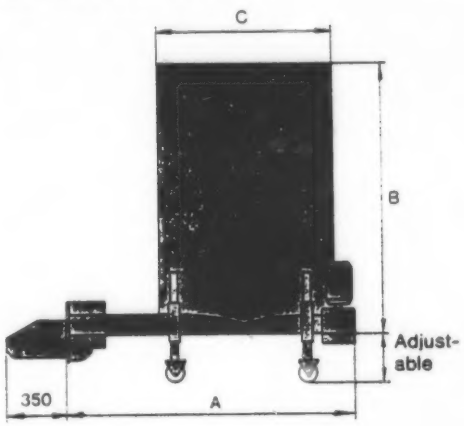
Chip storage with agitator, feeder screw and gear reduction motor. The bin has a hinged lid and a manual opening device.

Chip Volume m^3	Length m	Width m	Height m
2	2	1	1
4	2	1	2
8	2	2	2
9	3	1.5	2
16	4	2	2

Bottoms for chip storages with agitator and feeder screws can be delivered for installation in existing systems.

Chip burner with electrical ignition, stoker screw and gear reduction motor. Chip burners for 20 % moisture content in the fuel are available for 40, 50, 80, 150 and 300 kW. Maximum moisture content is 40 %.

Dimensions of a complete stoker unit.

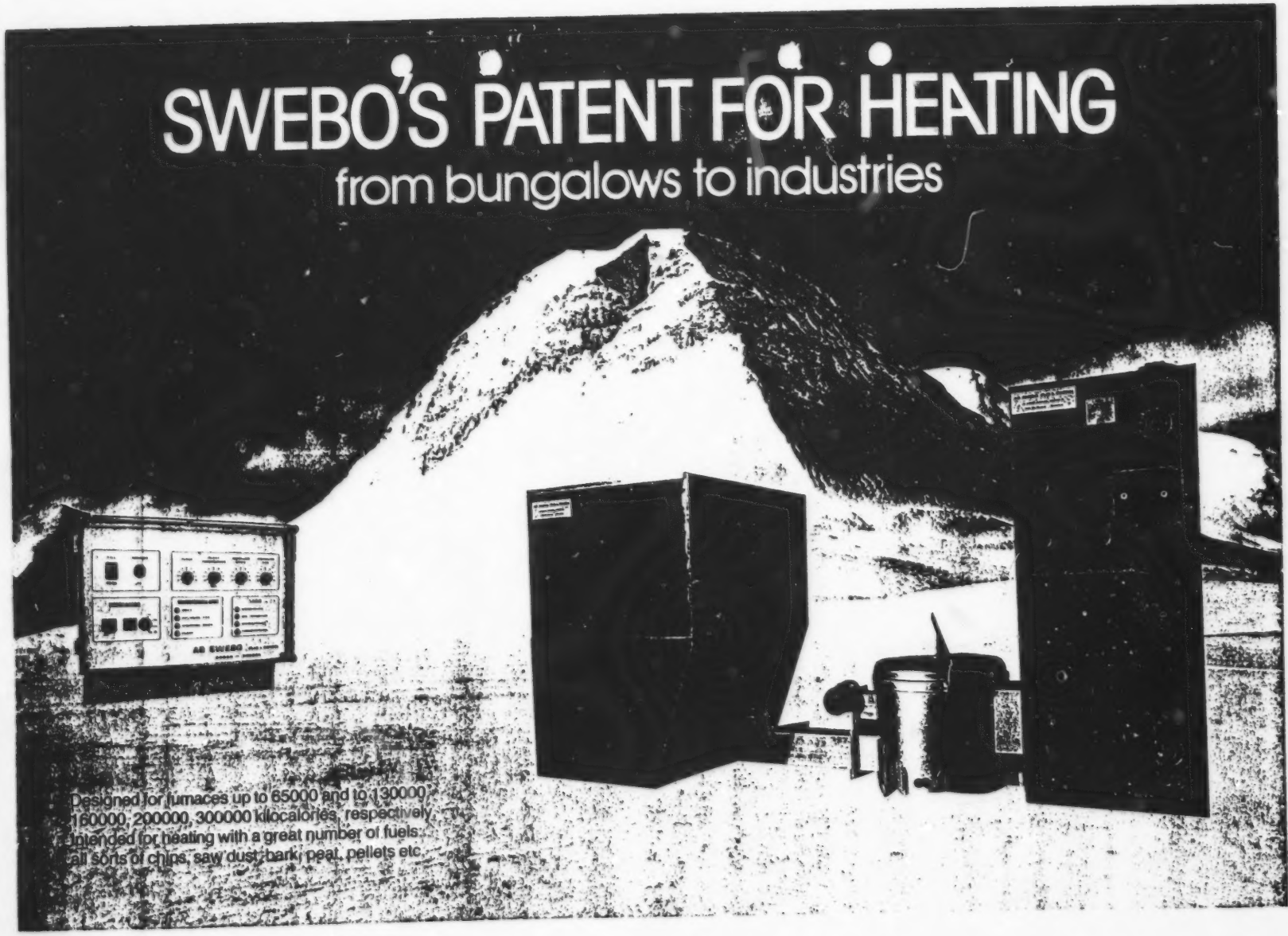


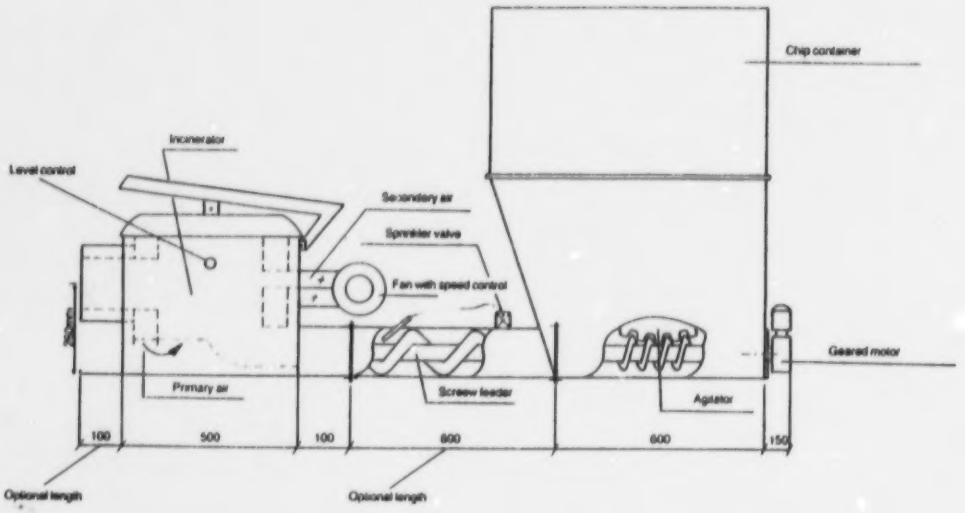
Measurement Data

Chip Volume in Liters	A mm	B mm	C=Width mm
300	950–1200	1000	640
600	1150–1400	1200	790

We reserve the right to alter data and dimensions.

AB VALLSTA MEKANISKA
PI 536 S-820 11 VALLSTA
Tel +46 278-456 58
Sweden


SWEBO'S PATENT FOR HEATING
from bungalows to industries
Designed for furnaces up to 65000 and to 130000, 160000, 200000, 300000 kilocalories, respectively. Intended for heating with a great number of fuels: all sorts of chips, saw dust, bark, peat, pellets etc.



Funktioning

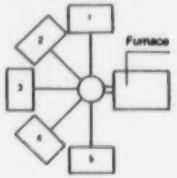
This chip-burning installation is built for reliability in heating. The agitator feeds successfully all sorts of fuel: saw dust, chips (coarse, fine or green), bark, peat, pellets etc. All fuels can be mixed. The chip-burning plant is equipped with an electronic control system which guarantees a perfect regulation of the combustion.

Description

The Swebo system for chip burning consists of a container provided with an agitator. The agitator is connected to a screw feeder which conveys the fuel to the incinerator. The fan provides for secondary and primary air supply.

More alternative connections

The incinerator can easily be connected to an already existing furnace. The placing of the container provides a variety of alternatives according to available space.



Specification

The complete construction for chip burning: 65-08.

Length	2100 mm or as required
Width	1060 mm or as required
Height	1200 mm
Shaft shoulder	230 × 230 mm
Chip container	800 alternatively 1200 litres

Container of 4,5 cu.m. can also be connected to a large silo.

The construction can be built according to requirement.

Operation economy

Make your own calculation:
1 cu.m. of piled wood gives approx. 1,7 cu.m. of chips. 12 cu.m. of chips give the same heating value as 1 cu.m. of oil.

Oil

I buy ..... cu.m. of oil p.a.

I pay ..... pounds per cu.m.

Oil costs ..... pounds

Chips

To let the chips have the same heating value as the oil
I need ..... cu.m. of chips.
(12 × the number of cu.m. of oil)

To get the same heating costs by chip burning as by oil burning I would only pay ..... pounds per cu.m. of chips.

Dealer: _____

Manufacturer:

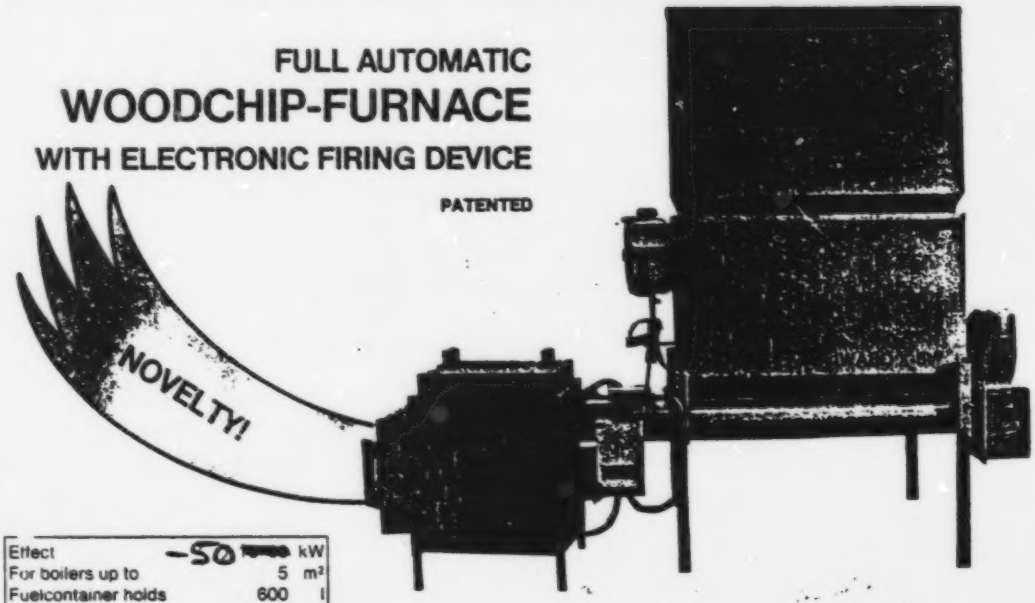
AB SWEBO FLIS & ENERGI
0921-152 54, 524 80 961 38 BODEN
Mobiltel. 010-580059 SWEDEN

TRYCKARNA BODEN

IWABO WOODCHIP HEATING

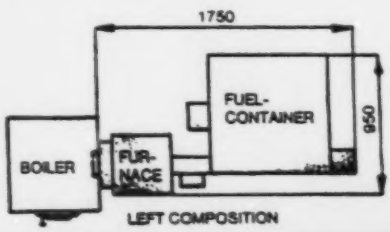
FULL AUTOMATIC
WOODCHIP-FURNACE
WITH ELECTRONIC FIRING DEVICE

PATENTED

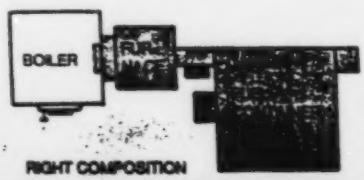


Effect	50	kW
For boilers up to	5	m²
Fuelcontainer holds	600	l
Height	1450	mm
Breadth	950	mm
Length before boiler	1750	mm
Electric connection	220	V

WORKS LIKE AN OILBURNER.
EXTREMELY RELIABILITY IN OPERATION.
THERMOSTATIC CONTROLLED ELECTRONIC FIRING DEVICE.
FOR FINE OR COARSE CHIP.
SAFETYSECURITY UNPARALLELED WITHIN CHIPBURNING.
ALL FUNCTIONS ON CIRCUIT CARD.
FIRE IS CONTROLLED BY A PHOTOCELL
- OPTIMAL REFRACTORINESS – SPRINKLERINSTALLATION.
SIMPLE ASSEMBLAGE – FITS MOST TYPES OF BOILERS.
1 YEAR GUARANTEE.



LEFT COMPOSITION



RIGHT COMPOSITION

BORGSTRÖMS INDUSTRI AB
S-823 00 KILAFORS, SWEDEN Telex: 47903 IWABO-S

BDR MACHINERY LTD.

November 1987

IWABOMATIC X-5 - SPECIFICATION

Length (assembled) = 1750 mm (69")

Width (assembled) = 950 mm (37")

Height (assembled) = 1450 mm (57")

* Can be hooked up to most existing boilers/furnaces with heating surface up to 4.5 m2 (50 sq. ft.)

* Dry as well as wet chips can be used.

* Output up to 50 kW (170,000 BTU/Hour) when fired with 20MC chips.

* Chip container volume 500 litres (17 cu. ft.)

* Electric Power Supply 220 volts Single Phase 10 Amps.

* Drive Motor 0.37 kW (0.5 HP) - 220VAC/3.1A - 1644 RPM

* Two Stage Worm Gear Reducer 364:1 Ratio

* Feed Auger diameter 84/30 mm x 68.5 mm pitch
  Feed Auger tube Ø 113/105 mm

* Chip Container with sloping bottom incorporating chain driven reciprocating agitator for positive feeding of chips.

* Shear pin protection and motor overload switch with reset button.

* Back fire protection with automatic sprinkler including low water level safety switch.

* Pre-combustion Chamber with grate, ignition coil, photo eye and safety switch for over-filling.
  Stainless Steel Housing.
  Insulation 70 mm thick.
  Ceramic walls 45 mm thick.
  Outlet nozzle made of heat resistant steel.

* Nymo patented Electronic PLC Control Unit with adjustable setting for:

  - Continuous firing or on-off mode when heat is called for.

  - Initial feed time before ignition.

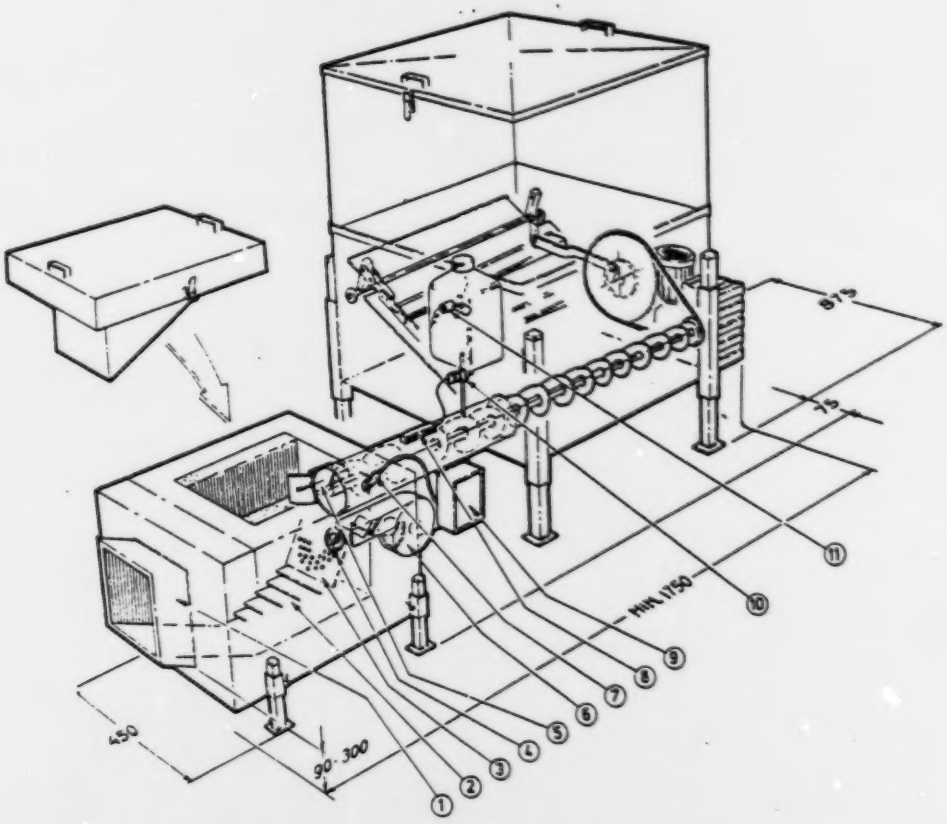
  - After burning time

  Fully automatic safe operation like an oil burner.

BDR MACHINERY LTD.

November 1987

IWABOMATIC X-5 - ASSEMBLY



1. Outlet Nozzle
2. Step Grate
3. Ignition Coil Plate
4. Ignition Coil
5. Overfill Safety Switch
6. Fan with Air Flow Control
7. Photo Eye
8. Sprinkler Sensing Bulb
9. Electronic PLC Controls
10. Sprinkler Valve
11. Sprinkler Low Level Switch

Udvikling, produktion og salg af fyringsanlæg.

Entwicklung, Herstellung und Verkauf von Feuerungsanlagen.

Développement, production et vente d'installations de chauffage.

Sviluppo, produzione e vendita impianti riscaldamento.

Dan Trim

SKRIVERSVEJ 8
DK 8800 VIBORG
TELF.: 06-673011
06-673283
TELEX: 66215 tvm dk
APS REG. NR. 46477
GIRO: 6 39 44 34

Mounting instruction for water cooled combustionhead type 1VU and 2VU and 2VBU.

Text for drawing no. 01-227.

1 Dan Trim Minimatic stoker.

2 Automatic air drainer, ¼" - ¾".

3 Safety valve, 2,5 Bar.

4 Water cooled combustionhead.

5 Boiler.

6 Flow thermometer.

7 Thermostate valve DTKT 72°. Ensure that the combustionhead is constant warm, 72 - 85° C. Is delivered as standard equipment with the combustionhead.

8 Double boiler thermostate for controling the stoker. To be mounted on the boiler.

9 Flow pipe, eventually flexible high pressure tube of reinforced steel. Ought to be slight increasing concerning airing.

10 Circulation pump for return water.

11 Flow to installation.

12 Thermometer for return water.

13 Return water to burner, eventually flexible high pressure tube of reinforced steel.

14 Return water from installation.

Notice the following:

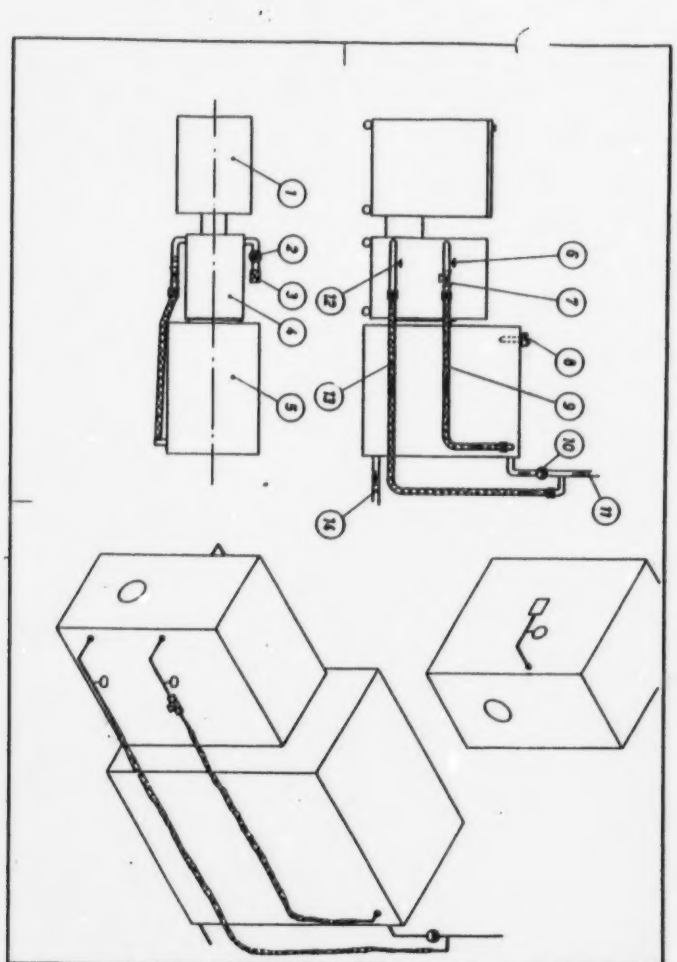
There shall always be pump circulation on the combustionhead when it is burning.

If the pump at existing installation isn't big enough to apply both installation and combustionhead, there can be used an extra pump and it is mounted after drawing no. 01-228.

Pump- and pipesizes:

Combustionhead no. 1 watercooled.	Grundfos	UPS 15-35	2 m3	2 m WS	¾"
- - 2 -	-	UPS 15-35	2 m3	2 m WS	1"

1.11.1985



Dan Trim A/S	Materiale	Model nr	Lager nr	Målestok ~	Tegn. 30/5 85	DD
Skriversvej 8					Kon.	
DK-8800 Viborg	Montageanleitung für Brennerkopf, Wassergekühlt, Typ 1-2 Mounting instruction for water cooled burner, Type 1-2 Montagevejledning for vandkølede brændere, Type 1-2			Tegn.nr. 01-227.		

1.00 Delivery, unpacking and mounting

Delivery : The stoker and the burner are delivered in a cardboard box mounted on a pallet. May be transported to the furnace room with a forklift or a pallet carriage.

Unpacking: Cut the tapes, remove cardboard box. Open the topdoor an the stoker and the ash pit on the burner. Take all components stored there and check:

Stoker: Feedingauger and possible miscellaneous equipment.

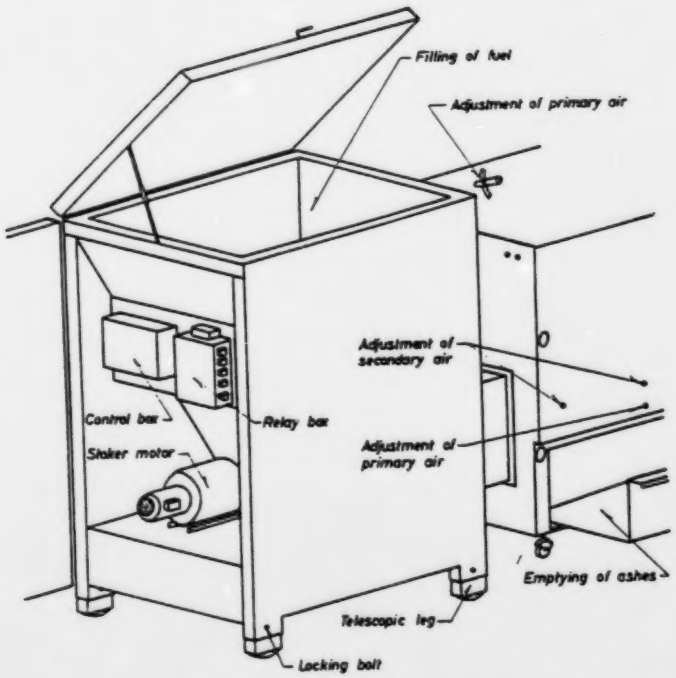
Burner: Ashauger, 3 airtubes, 6 clips, 2 Allen Keys, 1 gasket robe, 1 gasket between the stoker and burner, 1 flammemirror, 1 thermostatevalve, drawings for mounting the watercooled burner.

If any parts are missing or there is any damage, please inform the seller straight away.

Mounting : The stoker is mounted by your plummer or installer according to our directions, drawings no. 01-227 and 01-228. Feedingwheel is standardequipment and mounted inside the stoker. (Section 8.00)

Note: Always ensure that the topdoor is sealed tightly and securely locked, all removeable doors or panels on the boiler are in position and sealed. There have to be a sub presure on 2-3 mm present in the burner, when the stoker operates. If not a smokeexhauster can be mounted between the boiler and the chimney.

FIG. 1.



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TILLEY MANUFACTURING LTD.

SAWDUST/WOODCHIP HEATING SYSTEMS
RESIDENTIAL, COMMERCIAL-INDUSTRIAL
REPLACEMENT PARTS FOR HARVESTER & DIGGER

HERBERT M. GOODINE
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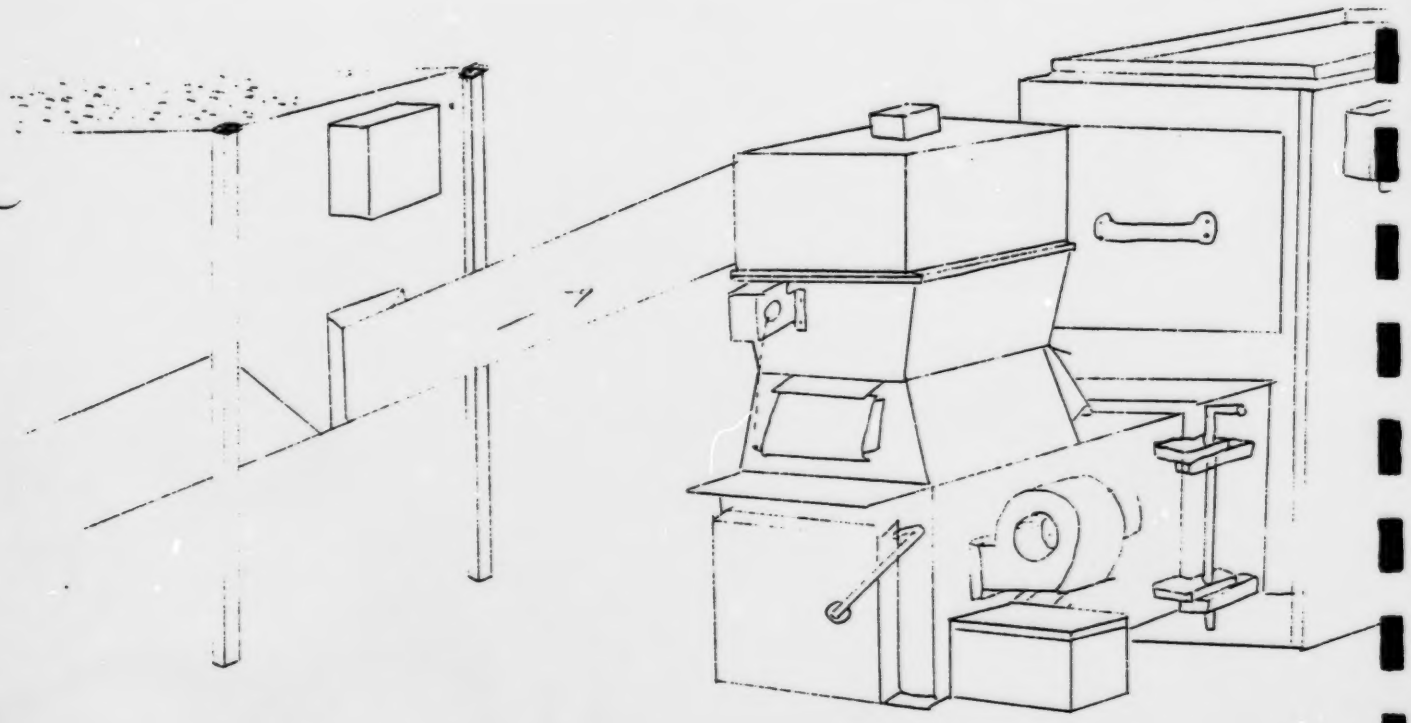


TILLEY MANUFACTURING LTD.
c/o Herbert & Kevin Goodine
R.R. 2, Arthurette, N.B. E0J 1C0
Phone 273-2462

Thank you for requesting information concerning our woodchip / sawdust Burner. Hope you will find this information usefull for your choosing the only American built AIR-cooled Tilley Burner.

This Burner is Fully automatic and has symple mechanical construction which alows Any type of Fuel Less then 25 mm chips to pass through. Best efficiency will be Recovered with M. C. Less than 50 %.

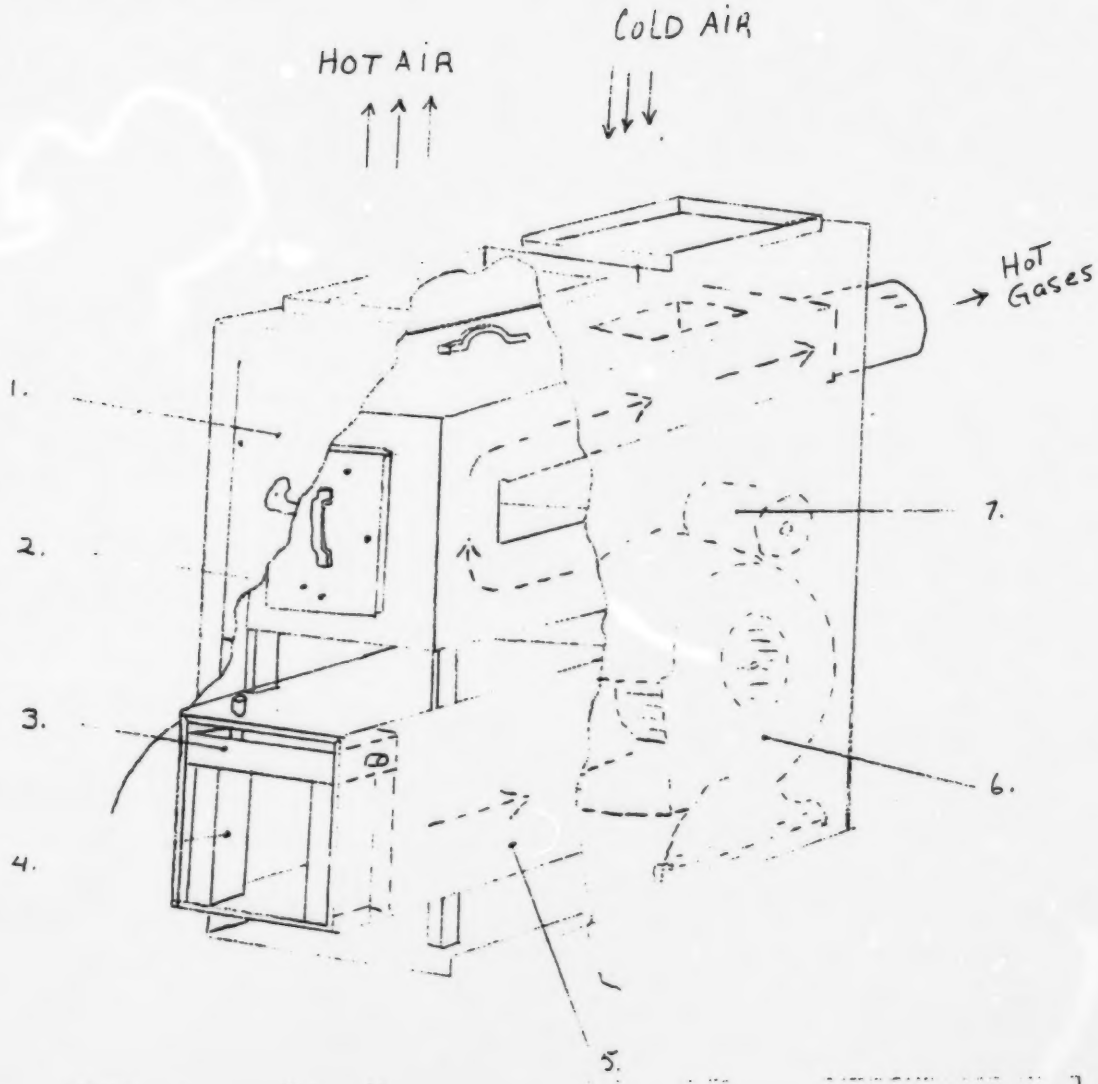
(GREEN HARDWOOD SAWDUST)

HEATING. CUB/FT x .15 = Fuel STORAGE CUB/FT

BTU/HR RATING	FLOOR SPACE L X W X H	FUEL CONSUMP. HR. MAX.	HEATING AREA CAP. CUB/FT	STORAGE SPACE REQUIRED CUB/FT
175,000	7X2X4	2 CUB/FT	16000	2880
212,000	8X3X4	3 CUB/FT	40000	7200
400.000	9X3½X4	4 CUB/FT	75000	13500

note.
* units may be HOT WATER OR FORCED AIR.
** Automatic Loading bend optional.

Fig 2



1. Shell Door
2. Clean out trap
3. Hot water tank
4. Fire Blocks
5. Heat exchanger
6. Cold air Blower
7. Fan motor

TILLEY MANUFACTURING LTD.
Phone (506) 273-2462

BTU./hour	Discription	Price
A) 175,000	Burner + Exchanger	2400.00
	Burner + Boiler	3000.00
B) 212,000	" + Exchanger	2800.00
	" + Boiler	3400.00
C) 350,000	" + Exchanger	5000.00
	Burner + Boiler	7600.00
A)	Add on only	1400.00
B)	Add on only	1600.00
C)	Add on only	2400.00

note: Automatic feeder is optional. Price is on request

* ALL PRICES INCLUDE AUTOMATIC CONTROLS AND HOPPER.
* ALL UNITS WARRANTIED FOR 2 YRS UNDER NORMAL OPERATING CONDITIONS.
* 8% SALES TAX

APPENDIX G

GUIDELINES FOR ROUNDWOOD BOILER DESIGN

APPENDIX G

GUIDELINES FOR ROUNDWOOD BOILER DESIGN

Among all the woodburning appliances that IRTA's lab has performance tested, domestic central heating systems, particularly boilers, have almost always performed poorly. Some of the boilers rated at a maximum output range of 100,000 Btu/h, have had emissions roughly 25 times above the EPA reference level of 8.5 g/h (maximum emission level for wood burning stoves sold in the USA). Boiler makers can no longer afford to overlook low efficiency and high emission levels. It is clear that public awareness in this area is increasing and new regulations to protect against atmospheric deterioration will be put in place.

Although no one has come up with the ultimate design, there are certain principles that emerge. The following guidelines are meant to increase awareness of boiler manufacturers to the physical principles which come into play when designing wood boilers. Boiler manufacturers should be able to incorporate these concepts into their own boiler design. This would provide a more efficient and cleaner-burning appliances.

We would also remind designers that no matter how good a design looks on paper, it can only be evaluated under operating conditions. Manufacturers who do their own design should also have a testing facility to evaluate their products. Otherwise, they are only guessing at the results of any modification. For evaluation purposes, we recommend that appliances be tested with an on-site dilution tunnel testing facility.

Wood burning technology is continually changing and improving. Designs that appear to be the best today will eventually make way for more innovative solutions to woodburning problems. The following guidelines are written with this in mind.

DESIGN GUIDELINES

1. Separate combustion chamber and heat exchange area

- combustion is more complete under higher temperatures: every effort must be made to keep the combustion chamber as hot as possible. It can be insulated with refractory material, cast plates, stainless steel linings, etc.

- to help maintain the combustion chamber as hot as possible, heat MUST NOT BE REMOVED from this area. THIS MEANS THAT THERE SHOULD BE NO HEAT EXCHANGE FROM AROUND THE COMBUSTION CHAMBER but rather from a heat exchange area which is separate from the combustion chamber. WATER JACKETS SHOULD NOT SURROUND THE WOOD COMBUSTION AREA, unless they are separated from the fire box by insulating material. Only after both primary and secondary combustion have been completed should we attempt to remove heat.

- if combustion air is pre-heated, it should not be with heat which is removed from the combustion chamber. Pre-heating may be done in the heat exchange area or outside the insulating jacket of the combustion chamber.

2. Provide good control over the primary air which is entering the combustion chamber

- primary air controls the rate of burn. It induces primary combustion, i.e. the first decomposition of the wood. Primary combustion air alone may not be sufficient for an efficient combustion. It is necessary to supply secondary air downstream from the fire to complete the burning of the products of primary combustion: carbon monoxide, tars, etc.

- primary air entering low at the front of an appliance equipped with a long baffle, will tend to promote a controlled primary burn, from front to back. In this type of appliance, hot primary air can be jetted into the stream of outgoing combustion gases. This can promote mixing of gases and air for better secondary combustion. If the primary air is directed at the base of the fire in a concentrated quantity, it may produce too rich a mixture and cause poor combustion.

- it is our opinion that on/off damper motor controls and draft regulator controls for primary air dampers do not provide the right type of management over combustion air. We see the necessity of developing a thermostatically controlled proportional air inlet, similar to that found on bimetallic primary air dampers. While the technology exists, to our knowledge it has not yet been adapted to solid fuel burning appliances.

3. A supply of secondary air fed at a strategic location in the combustion chamber is necessary to promote a more complete combustion of the wood gases. As stated previously, primary air cannot be expected to complete the combustion: the task of primary air is to regulate the rate of combustion in the gasifier section.

- a properly positioned supply of jetted secondary air must be introduced downstream from primary burn, in a very hot, insulated area. In updraft boilers, this will be immediately above the primary combustion chamber. In downdraft appliances, secondary air has often been seen as unnecessary due to the "very high temperatures" of combustion by-products. We do not hold this view. We maintain that these downdraft boilers should feed less primary air. Secondary air should not be expected to filter through the primary burn area. It should be fed directly to the secondary burn area.

- there must not have been any voluntary cooling of combustion gases before these reach the secondary burn area. Conversely the appliance should be designed to maintain hot gases until they get past the secondary burn area. As a rule, there should be no cooling in any area that maintains flames.

If secondary combustion is successful, it raises the boiler's combustion efficiency and reduces its particulate emissions.

- secondary air supply should be sized to the appliance's heat output. While the correct sizing is usually determined by performance testing, we have found that secondary air openings of 6 square cm per 100 MJ/h output (1 in^2 for every 100,000 Btu/h output) provides good results.

4. Smaller combustion chambers favour a lower level of emissions.

- our experience to date on a variety of combustion chamber designs and sizes has shown that it is easier to promote more complete combustion in smaller combustion chambers.

5. Do not oversize heat exchange area

- keeping in mind that even when a cleaner burn has been achieved, combustion gases still contains particulate matter and unburnt tars as well as large amounts of water vapour. In order to maintain a proper draft in natural draft boilers, the gases must leave the appliance with sufficient heat to maintain the draft which continues to drive the combustion. In all wood burning appliances, unburned combustion products still remaining in the flue gases should be vented to the atmosphere. To achieve this, the heat exchange area should be sized to prevent condensation on the heat exchange surfaces or in the flue pipes and chimney, under normal operating conditions. Excessive creosote condensation in the heat exchange area will corrode the metallic surfaces, reduce

gas passage area and reduce the heat exchange capacity. It is therefore better to reduce the heat exchange area by design. Flue gases leaving the appliance should be above 100°C in normal operating conditions.

6. Wood boilers require easy access for periodic maintenance.

- wood contains approximately 1% ash. While most of this ash remains in the combustion chamber or in the ash pit, some finds its way to the heat exchanger. The heat exchange area also gets coated with creosote and carbon particles. In forced draft appliances, a large part of the ash is deposited in heat exchange areas. Wood burning boilers designed for domestic or small commercial use should provide for easy access to ash deposit areas.

- manufacturers should provide an easy access to heat exchange areas for cleaning and should provide the necessary tools to perform this task easily and efficiently. Ash removal doors and ash trays with handles are good ways of simplifying this task.

- we have found that vertical tube boilers, if provided with easy access, simplify the task of cleaning the heat exchanger and for removing the fallen material.

- forced draft boilers should have cyclone dust collectors between the flue collar and the flue pipe.

7. Wood boilers equipped with oil burners should provide heat protection for burners

- oil burners are often fitted to wood boilers for convenience; if the heat output from the wood part does not match the demand, then the oil burner automatically kicks-in.

- oil burners should be positioned in wood boilers in such a way as to be protected against the intense heat during wood combustion. While the oil burner's protrusion into the combustion chamber may be shielded from the wood combustion flames, we must ensure that the system remains automatic and not require the removal of protective shields before the oil burner can be operated.